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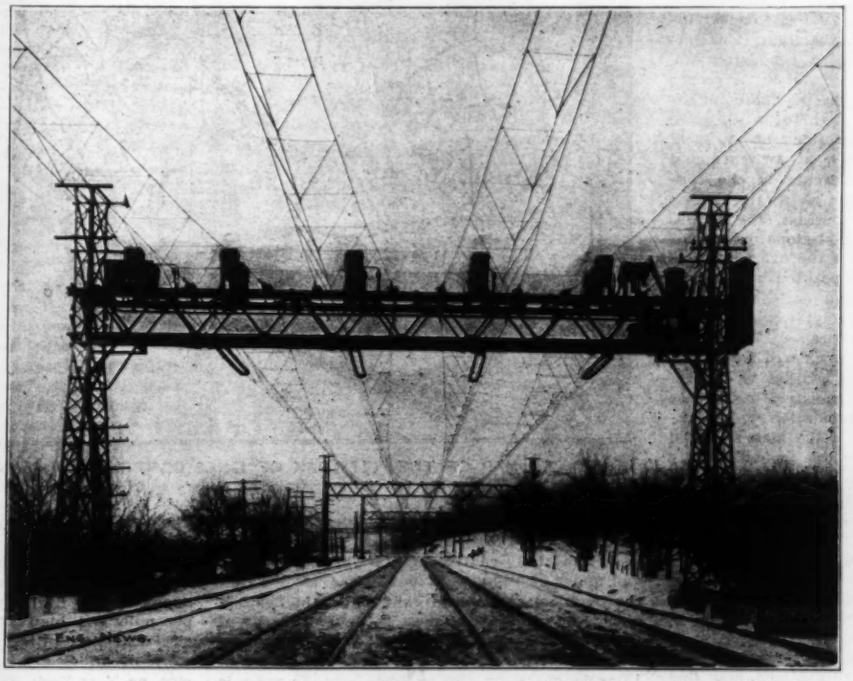
THE INSTALLATION OF ELECTRIC TRACTION ON THE NEW YORK TERMINAL SECTION OF THE NEW HAVEN RAILROAD.

Chapter 425 of New York State Laws of 1903 provides for the substitution for steam of some other motive power not involving combustion on the tracks of the New York & Harlem Railroad Co. in Park Avenue, south of the Harlem River, New York City. This mandatory act, therefore, applies to the motive power not only of the New York Central and Hudson River Railroad, which leases the New York & Harlem R. R., but also of the New York, New Haven & Hartford Railroad Company, which has trackage rights over the New York & Harlem R. R. from Woodlawn Junction to the Grand Central Station, under an agreement dated March 17, 1848.

In accordance with the terms of the act, an agreement was entered into between the city of New York and the New York Central, lessees of the New York & Harlem R. R., under which not only was the motive power to be changed, but also radical improvements were to be made in the Grand Central Terminal. This agreement requires the complete change of motive power within five years from the date of the filing of the approved plans, which makes the date of completion July 1, 1908. As there was no available motive power other than electricity that would meet the conditions of Chapter 425 of the Laws of 1903 and the agreement with the city of New York, it accordingly became necessary for the New York Central to provide suitable locomotives, track equipment and other means for electrically operating all trains in Park Avenue south of the Harlem River, and it also became necessary for the New Haven to arrange for a change from steam to electricity for the haulage of its own trains, as provided for by trackage agreement of 1848.

The New York Central, going beyond the legal requirement, extended the zone of electrification northward from the legal limits of the Harlem River to a considerable distance above Woodlawn Junction, and early adopted a system involving the use of direct-current motors taking current from a third rail, the generation of alternating current at 11,000 volts and 25 cycles, and the distribution of this current to substations approximately 5 mi. apart, where it is transformed to 666 volts direct current.*

The New York, New Haven & Hartford similarly took the view that it was desirable to extend the required electric terminal haulage over a section embracing at least the entire connecting or suburban district, and therefore decided to install electric equipment on its lines from Woodlawn, N. Y., to Stamford, Conn., a distance of 21 mi. This, with the 13 mi. to the Grand Central Station over which the trackage rights extend, makes a present haul of 34 mi. for the New Haven electric locomotives. It was thought best to undertake the electrification of this small portion of the New Haven system in such a way as to provide for future developments and extensions of the electrical system. The joint operation over the tracks of the New York & Harlem restricted the choice in the selection of a system of traction. It was obvious that no system inconsistent and inoperative with the installation of the New York Central could be adopted. This limited the choice to the low-voltage system of the New York Central, or the newer high tension single-phase system, the latter being able to operate also on low-voltage direct current. The development of single-phase traction has been briefly traced in previous issues of this journal.* With this system, the power is applied directly from generator to locomotive at the initial voltage and frequency without the frequent and necessary reductions and transformations of the direct-current third-rail system, as installed by the New York Central. It obviates the necessity of static and rotary transformers, of storage batteries, of low-tension switchboard, distribution and contact system, and affords the economy of high-tension transmission over long distances.



ANCHOR BRIDGE, OVERHEAD CONSTRUCTION, NEW YORK, NEW HAVEN & HARTFORD R. R.

Shortly after July 1, 1907, the use of steam locomotives was nominally discontinued on all service into Grand Central Station, New York City. The substitution of electric locomotives by the New York Central & Hudson River R. R. is complete. The New York, New Haven & Hartford, however, is compelled to run a few steam locomotives into the terminal on account of slow deliveries of apparatus from the manufacturers. It is seen that the electric service of both roads is far enough advanced to insure the complete fulfilment of the legal requirements considerably in advance of the time fixed.

The New Haven Company was one of the earliest pioneers in the field of heavy electric traction, and has operated six of its shorter branch lines by electricity in commercial service for a number of years past, beginning as early as 1895. Three of these lines, aggregating 33 miles in length, were equipped for overhead contact, and the remaining lines, aggregating 33½ miles in length, for third-rail contact. All lines were operated with 500-volt continuous-current motors, supplied from main stations and substations of the familiar type. The third rail was rather primitive in form, and without protective devices of any sort. So many fatalities and injuries followed the use of this method of supplying current to the motors that the railroad company was compelled to abandon all third-rail operation in Connecticut and revert to steam service,

*The entire system of the New York Central & Hudson River R. R. was described at length in an illustrated article in Engineering News of Nov. 16, 1905.

*Engineering News, Oct. 2, 1902; Dec. 17, 1903; Aug. 25, 1904; Apr. 7, 1904; Mar. 22, 1906.

by a decree of the Superior Court, dated June 13, 1906, and it now has no third-rail service excepting a junction overlap with the New York Central road at Woodlawn. Improved methods of protecting the third rail were available which would have considerably mitigated the more dangerous features of the earlier installations, but the unfortunate and unsatisfactory experience of the railroad company with this type of construction influenced its decision in favor of the single-phase system, which was finally adopted after a careful and complete investigation of the relative merits and disadvantages of the two methods of construction.

Had the study of the question been limited to the equipment of the terminal section in New York City, considerations of uniformity and expediency would doubtless have influenced the decision in favor of continuous-current motors taking curent from a third rail. The New Haven Co., however, recognized the great importance of its decision in its far-reaching effect upon future extensions of electric service to other parts of its system, and the final decision was based upon a study of the subject as a whole, rather than upon the solution of the terminal problem only.

While both methods under consideration included high-tension transmission by alternating current, it was believed that for many reasons the combination method requiring transforming devices and continuous-current motors was less well adapted to the conditions than its simpler single-phase competitor. The electric efficiency of the present third-rail system between power-house bus bars and engine shoes is 75% only, as compared with 95% for the single-phase system. The flexibility of the former is impaired by the limited radius of the secondary low-tension distribution, requiring substations at frequent intervals, and still further by the limitations imposed by the use of a third or conductor rail. The position and height of this rail in its proper relation to the track rail must be rigidly maintained, and the practical margin of permissible variation is measured in fractions of an inch. Also, its continuity is broken at switches and crossings by frequent transference of the conductor rail to the opposite side of the track or to an overhead position. In contrast, the single-phase system requires no substations or secondary circuits; the continuity of the overhead conductor is complete, and its position and height may vary within vertical and horizontal limits of 8 ft. and 4 ft., respectively, without losing contact with the collecting bows.

Various alternatives were considered before fixing the generating and transmission voltage of the system. It was at first proposed to increase the economic radius of transmission to the utmost by generating current at the highest initial voltage for which the generators could be safely designed (about 22,000 volts), and to provide substations at suitable intervals, equipped with static transformers, for supplying current at 3,000 to 6,000 volts to secondary contact circuits. As the two motors in each electric locomotive truck are permanently connected in series, and each takes 280 volts, current must be supplied at 560 volts through the transformer forming a part of the locomotive equipment. It became evident, however, that a great gain in simplicity would result if the intermediate substations and line transformers could be cut out altogether, and further study demonstrated the possibility of effecting this by reducing the initial E. M. F. to 11,000 volts and raising the ratio of the locomotive transformer to correspond. This was carried into effect with a resulting reduction in initial and operating cost, coupled with an increase of electrical efficiency, which, it is stated, proved most gratifying to the New Haven officials. Incidentally, the difficulties in designing satisfactory collecting devices were greatly diminished.

The determination of the most economical and desirable frequency of the transmission system involved the consideration of many factors entering into the problem. The choice of frequency was practically fixed by the manufacturing companies within limits of 15 and 25 cycles, and the comparative merits of these two, only, were considered. The lower frequency afforded a material reduction in weight, size and cost of motors, a reduction in conductor losses and induction disturbances, together with an increase in the power factor of the motors. Per contra, its adoption would have materially impaired the commercial value of the system as a whole, in restricting or preventing its extension for many other uses incidental to railway operation. The standard power and railway frequency in general use is 25 cycles, and as the New Haven Co. already owned a number of power houses generating current at this frequency for standard trolley operation, and, in addition, had equipped many of its shops with 25-cycle motors, the adoption of 15 cycles would have required the abandonment of a large amount of apparatus, or the interposition of costly and inefficient means of translation. The lighting of stations and other buildings was quite an important factor also, as 25 cycles is the lowest frequency at which the carbon filament lamps in general use can be satisfactorily operated. It was also considered desirable to provide for operation in parallel with the 25-cycle generators already adopted by the New York Central Co. The practical effect of a change from 25 to 15-cycle apparatus would thus be substantially equivalent to a "break in gage," and under existing conditions it was decided that the practical commercial value of the higher frequency outweighed the more theoretical merits of the lower one.

Should future considerations warrant the use of 15-cycle operation the change from 25-cycle is easy and inexpensive. Mr. B. G. Lamme, M. Am. Inst. E. E., in a discussion of a recent paper, said:

> The single-phase series motor can be made to operate on both 15 and 25 cycles. A 25-cycle motor will operate beautifully at 15 cycles and at practically the same speed because the speed has nothing to do with the frequency. By taking a 25-cycle equipment and putting a 15-cycle transformer on it, the equipment is adapted for operation on both 25 and 15-cycle systems. This is important in connection with the fact that 25 cycles will have to be used in a certain number of cases, but in other cases where generating conditions can be made suitable, 15 cycles will work to better advantage.

Although it may be said that the present electrified section of this road is short, comprising the 21 mi. of four-track line between Woodlawn, N. Y., and Stamford, Conn., yet it is evident that under the plans of the New Haven management when, in the course of years (perhaps generations), they become fulfilled, the vast network of lines throughout southern New England will be operated electrically.

Any general change, in a comparatively short period of time, from steam to electric operation would render unproductive a large amount of capital and necessitate the expenditure of large additional amounts, but when the change is spread over a large number of years the introduction of a new system may progress at about the same rate as the scrapping of the steam traction apparatus. Many analyses and comparisons of the costs of steam and electric railroad operation which have been published and discussed tend to show that a considerable reduction in fuel, repairs and operating expenses may be expected. Administrative officials will recognize this when the returns of the smaller beginnings show the saving, and the extension then may be looked for beyond the present very favorable conditions of congested terminals, high frequency of train service and low power cost.

What may be expected then in the extension of the New Haven system is the gradual electrification of the shore line to Providence and Boston, and later of the network of lines inland.

FIG. 2. MAP OF THE NETWORK OF LINES COMPRISING THE NEW HAVEN SYSTEM.
(Showing the probable location of power-house centers as determined by a 20-mile transmission radius.)

The situation of the various lines of the system is especially favorable for a complete extension of the adopted system, which promises, on account of the very network of lines, to give great advantage for flexibility, continuity, low first cost per mile and high efficiency of operation. The electrical distribution will be analogous to a network of an electric lighting system of a great city, as New York, Boston or Chicago.

A glance at Fig. 2 will show how the New Haven system comprises a network of lines, and will indicate that its transmission must be worked out for areas rather than for linear distances, thus reversing the ordinary conditions. As the area served increases as the square of the radius of transmission from the generating center, and as there may be several circuits in the network serving as paths to common points of use, it is evident that ordinary methods of calculation will be greatly modified. Under such conditions, the economic radius corresponding to any initial potential will be considerably extended, and the commercial and practical value of high-potential transmission will be much increased. The map shows the network of lines and probable location of power stations, the latter on the supposition that such a network is served

by stations having, roughly, a 20-mile radius of transmission well within the limits of line loss and regulation.

The following description of the installation now in operation between Woodlawn Junction and Stamford is arranged from authentic information and data furnished by Mr. E. H. McHenry, Vice-President of the New York, New Haven & Hartford R. R. Co.

OVERHEAD CONSTRUCTION.

It has been stated that the New Haven locomotives are adapted to use on the direct-current 600-volt third-rail system installed on the New York & Harlem property. The alternating-current construction, then, commences at the New Haven road's junction, Woodlawn.

The very high voltage of the New Haven system necessitated supporting the overhead conductors in a most substantial and secure manner, so that a catenary construction was adopted. Broadly speaking, this consists, for each track, of two steel cables swung between steel bridges 300 ft. apart, assuming the natural catenary curve, with the trolley wire supported from these by stiff triangular steel frames about every 10 ft. and maintaining the trolley closely parallel to the track grade.

As will be seen from the photograph, Fig. 1, the supporting cables are "cradled," i. e., they have a catenary form in their projection on a horizontal plane as well as in vertical projection. This gives greater rigidity and prevents swaying of the wire structure. The whole system of catenary supports and trolley wires carries current and is insulated from the bridges. Where the cables pass over the steel supporting bridges they rest upon massive porcelain insulators. At intervals heavier bridges are provided against which the cables are anchored by means of specially constructed strain insulators.

The steel supporting bridges are of varying lengths, so as to accommodate from 4 to 12 tracks, as the local conditions require, without the necessity of placing posts between tracks. These bridges are of a uniform design and consist of latticed steel-angle construction. The intermediate bridges are of course much lighter than the anchor bridges, which are only used at intervals of about two miles. The intermediate bridges have side posts of square cross section and comparatively light construction. The anchor bridges have A-shaped posts, and are made of proper strength to withstand the stress of the cables.

The general appearance of the standard four-track intermediate bridge is shown in the background in Fig. 1. It consists of two supporting side posts and a horizontal truss. Each supporting post is approximately 38 ft. long by 1 ft. 10 ins. square, and is composed of four 4 × 4 × 7-16-in. angles, secured together by 2¼ × ⅝-in. lacing bars. Each post rests upon a foundation which contains about 9 cu. yds. of concrete. Anchor bolts extend entirely through the concrete foundation, and hold the base of the post to the foundation by means of heavy nuts. The cross truss is attached by means of bolts to the vertical posts, allowing a distance of 23 ft. 4 ins. from the lower side of the truss to the top of the rails. The truss is 4 ft. 6 ins. deep from back to back of chord angles, and the two angles of each chord are spaced horizontally 1 ft. 10 ins. b. to b. The lacing bars of the upper chord are depressed below the upper surface of the chord angles, so that the latter are left free from rivets or other obstructions, thereby affording a ready means for attaching the insulators at any point. The lacing bars of the upper chord consist of flat straps, while the diagonals in the sides and bottom of the truss consist of angles. The upper chord angles are 6 × 3½ × ⅝-in., and the lower are 4 × 3½ × 5-16 ins.

The extensions of the side posts above the trusses are utilized for supporting wires, which are carried upon steel angle cross-arms bolted to the posts. The lower arm carries two insulators, upon the inner one of which is supported the pass-feeder, while the outer carries an auxiliary supply. The upper cross-arm is located 5 ft. above the lower one and carries two wires of a subsidiary three-phase circuit. The third wire of the three-phase circuit is carried upon a light vertical channel iron support which is not shown in the illustration.

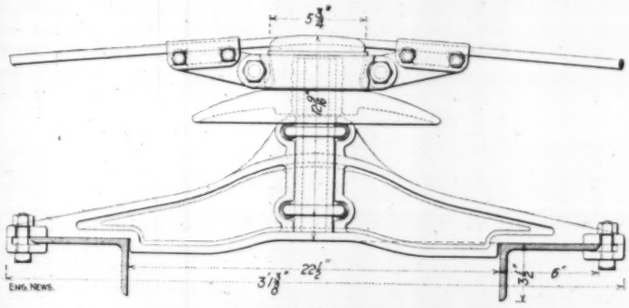


FIG. 3. INSULATING SUPPORT FOR CATENARY CABLES.

In the calculation of these bridges, very heavy weather conditions were assumed, and provision was made for clamping the catenary cables on the intermediate bridges so that the latter are obliged to partially withstand the longitudinal pull of the cables. It was assumed that the entire system of bridges and cables might become coated with sleet, and that this coating might be ½-in. in thickness around all surfaces. Under these conditions it was assumed that the wind pressure on the bridges and the catenary spans might be as high as 25 lbs. per sq. ft. It was further assumed that the effective area of all round cables would be two-thirds of their projected areas. Each catenary cable is clamped to its suporting insulator on every intermediate bridge. While under these conditions, if one pair of cables should be broken, the remaining cables would exert a balancing influence on the bridge; the truss was, however, made strong enough to prevent its buckling under the strain produced by the breakage of any single pair of cables.

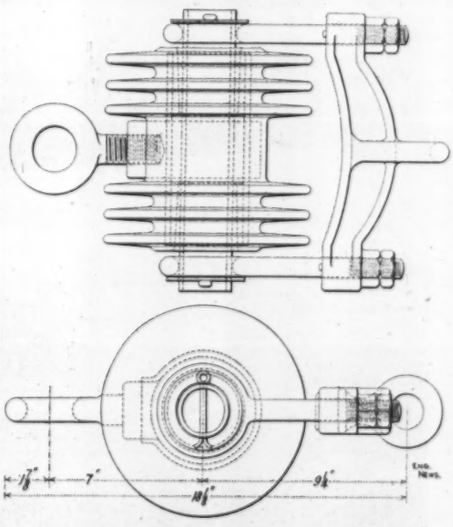


Fig. 4. Anchor Bridge Strain Insulator.

ANCHOR BRIDGES.—Anchor bridges of especially heavy construction are placed every two miles, and against these bridges the catenary cables are anchored. Fig. 1 shows a standard four-track anchor bridge with the auxiliary apparatus mounted upon it. The four-track anchor bridge consists of two A-shaped posts having a spread at the base of 15 ft. and a width at right angles to the track of about 2 ft. The main members of the posts consist of 6 × 4 × ⅝-in. angles. These posts are also extended above the truss in the manner shown in Fig. 1 for the purpose of carrying the pass-feeder wires. The truss is bolted to the side posts, allowing a clearance above the rails to the lower side of the truss of 24 ft. 3 ins. The truss is 4 ft. 6 ins. deep by 5 ft. wide between the backs of the chord angles. The upper chords consist of 8 × 8 × 9/16-in. angles, and the lower chords consist of 4 × 3½ × 9/16-in. angles. The anchor bridges also carry lightning arresters, transformers for operating the circuit-breakers, together with foot walks, hand railings, lighting circuits, and the wires and conduit for the auxiliary control circuits.

The deck of an anchor bridge is shown in Fig. 7, from which additional details of the construction may be noted. A ladder is provided on one of the posts leading to a small platform at the end of the truss. This platform is provided with a handrail and carried upon it is a box containing an 11,000-volt, "low equivalent" lightning arrester. A portal is provided in the end of the truss by means of which the attendant may step onto the platform supported on the lower chord of the truss. The anchor bridges are secured to concrete foundations by means of long anchor bolts and nuts. Each post rests upon two blocks of concrete, each block containing about 12 cu. yds. of concrete, in the case of the four-track bridge.

CATENARY CABLES.—Each of the two catenary cables which support the trolley conductor consists of an extra high strength 9/16-in. steel cable, composed of heavy strands. This steel has an ultimate strength of about 200,000 lbs. per sq. in., and each strand is heavily galvanized. The completed cable has an ultimate total strength of 33,800 lbs. These cables are strung between the bridges, with a sag at mean temperature of 6 ft. in a standard span of 300 ft. Owing to obstructions at certain places along the right-of-way the spacing of the bridges is occasionally varied from the standard 300 ft. In order to allow for this, the cable is run out in long lengths and is pulled up to a uniform tension until the sag in the span of 300 ft. is 6 ft. The sag in the outer span is allowed to adjust itself, since the tension is the same. After this the cables are anchored to the anchor bridges and are clamped to the insulators of the intermediate bridges.

MAIN LINE INSULATORS.—The heavy porcelain insulators which support the catenary cables on the intermediate bridges are shown in Fig. 3. They are 15 ins. in diameter and about 7 ins. high. These insulators are cemented upon short lengths of double extra strong pipe which in turn are held by means of U-bolts to a cast-iron yoke bolted to the upper chords of the truss. The catenary cable rests in a groove in the top of the porcelain and is held by means of a malleable iron clamp fitted with U-bolts and placed one on each side of the insulator. The head of the insulator is conical in shape and is surrounded by a split malleable iron clamp and a lead packing.

One notable feature of the construction is the arrangement of the clamp and the collar, which is such that in case of the breakage of the messenger cable on one side of the insulator the pull of the cable on the other side will cause the clamp to swing downwards, thereby lowering the point of application of the pull of the cable, so that the porcelain is put in compression and there is no tendency to shear off the top of the porcelain, as is usually the case with porcelain line insulators. Each insulator is subjected to a shop test of 55,000 volts.

ANCHOR BRIDGE STRAIN INSULATORS.—The insulators which are used for dead-ending the catenary cables at the anchor bridges, shown in Fig. 4, are of special construction and are designed to stand a shop test of 50,000 volts and a working load of 20,000 lbs. They consist of a length of 2-in. extra heavy iron pipe, surrounded at its middle point by an iron collar.

Outside of this collar a long insulating tube, composed of an especially hard and reliable insulating material, is pressed. A second collar surrounds this tube, into which a bolt is screwed and to which the turnbuckle of the catenary cable is attached. The entire surface of the insulating tube and the inner and outer collars are then effectively sealed against moisture by means of a high-grade insulating compound applied by means of hydraulic pressure. The insulator thus made up is supported by means of an iron yoke from hooks bolted to the upper chords of the anchor-bridge truss. One of these insulators is provided in each catenary cable at each anchor bridge, thereby dividing the road into separate sections between the anchor bridges.

TROLLEY HANGERS.—The trolley wire (No. 0000 B. & S. gage grooved copper) is supported from the catenary cables, at intervals of 10 ft., by means of equilateral-triangular trolley hangers of varying lengths. These hangers are so adjusted in length that the trolley wire is maintained in a horizontal position at mean temperature, it being 6 ins. below the catenary cables at the middle point of the span. It follows that the distance between messenger cables is roughly the same as the distance from the trolley wire to either cable and that at the anchor bridges the trolley wire is slightly more than 6 ft. below the plane of the catenary cables. They carry at the lower end a pair of small drop-forged steel jaws which engage with the grooves of the trolley wire and are clamped by means of a malleable iron Y, which is screwed down on the threaded portions of the jaws. Two sides of the triangle are then screwed into the Y and are bolted to the messenger cable above. As all of the threads are right handed, it is impossible for the hanger to come loose. This hanger construction is shown in Fig. 5.

PULL-OVER HANGER.—At the points, on curves, where the pull-over wires are attached to the catenary span a triangular hanger of heavy construction is provided. It consists of malleable iron clamps, which are attached to the two catenary cables and into which short lengths of heavy pipe are threaded. At the lower end of the triangle is provided a malleable iron casting. This is threaded into a heavy bronze clamping ear, which is attached to the trolley wire. Loops are provided for attaching the pull-over wires at such a point on the hanger frame as to hold the trolley wire directly under the catenary cable.

INSULATING SEPARATORS.—In order to enable any one track to be electrically disconnected from any other parallel track when the circuit-breakers on the anchor bridges are open, insulating separators are provided in the pull-over wires between the tracks. They consist of long rods of selected hickory thoroughly impregnated and fitted at the ends with malleable iron heads secured to the conical heads of the rods by means of bolts. These insulators have an ultimate tensile strength of about 16,000 lbs.

At no point in the entire construction is wood relied upon for insulation to the ground, and it will be noted that these wooden separators normally have no difference of potential upon them. They are merely provided for service in case of accident, when it is necessary to isolate one section of track from another.

TROLLEY SECTION BREAK INSULATORS.—At each anchor bridge it is necessary to provide an insulator in the trolley wire, and this is accomplished by means of a piece of apparatus consisting of two bronze end castings to which the ends of the trolley wire are bolted. Two parallel sections of impregnated hard wood are fastened to these castings, and to these wooden strips are fastened renewable pieces of trolley wire in such a manner that the ends of these renewable pieces overlap each other. By this means it is possible for the sliding contact on the locomotive to pass from one section to the next without opening the circuit, thus avoiding all flashing. It will be noted, however, that an effective insulation is provided so that when the circuit breaker on the anchor bridge is open the two sections will be discontinuous. The section breaks are shown in Fig. 1, under the anchor bridge.

LOW BRIDGE CONSTRUCTION.—At a number of points along the road overhead street bridges reduce the clearance above the tracks, and at these points special construction is used, consisting of a long, corrugated porcelain tube on an iron pipe carried by means of the pipe fittings and petticoat insulators from the lower side of the bridge. The messenger cables, where

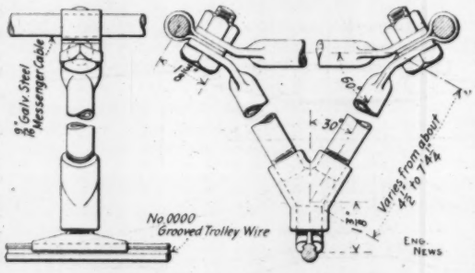


Fig. 5. Trolley Hangers, Overhead Construction.

they pass under the bridge, are heavily insulated, and the hangers which support the trolley wire from the messenger cables are placed midway between the porcelain insulators, so that the maximum amount of flexibility is obtained. The trolley wire hangers are constructed of impregnated wood, so that the trolley wire is completely insulated from the catenary cables. A waterproof dirt shield is attached to the bridge above the insulated structure. This construction is shown in the view, Fig. 6.

AUTOMATIC CIRCUIT - BREAKERS. — The circuit-breaker is carried by a cast-iron framework bolted to channel irons resting on the upper chords of the anchor bridges. This framework carries an iron box provided with a hinged weatherproof cover. The box contains the moving parts of the circuit-breaker, which are made especially strong and reliable in their operation. The terminals of the switch are brought out through specially-constructed insulators mounted in an overhung portion of the box at the rear. Upon the tops of the insulators are carried knife-switch jaws, and there are corresponding jaws mounted on the upper ends of the circuit-breaker contacts. Two switch blades are carried on insulating pillars so fastened to the [illegible]ed cover of the box that when the cover o[illegible]e box is closed one terminal of the switch [illegible]onnected to the bus-bar on the anchor bri[illegible] and the other is connected to the trolley wi[illegible] Arrangements are provided so that if the co[illegible]s opened the circuit-breaker will be automati[illegible] tripped so as to prevent any possibility of t[illegible]ttendant taking hold of the live parts.

The circuit-breaker is an oil switch [illegible] the automatic type, and is capable of han[illegible]g 11,000 volts on heavy short circuit. A tripping coil, arranged to open automatically on o[illegible]rload, is provided, together with a closing magnet, both of which are operated from a circ[illegible] supplied from a 5-KW. transformer on the anchor bridge. The control wires for the closing magnets and the tripping coils are carried in iron conduit and lead-covered cable to the signal towers and to an adjoining shack where a switchboard panel is provided. This panel is fitted with switches so that any circuit-breaker may be tripped or closed there by hand. This control is normally by the attendant in the nearest signal tower. Control of a single circuit-breaker is shown in Fig. 8. For simplicity, only one such control circuit of the eleven is shown, and only to the adjoining house.

TRACK BONDING.—Both rails of all tracks are bonded by means of No. 0000 compressed terminal flexible bonds placed round the fish plates.

TURNOUTS AND CROSSOVERS.—Wherever one track diverges from another a section insulator is inserted in the trolley wire and the catenary cables of the turnout or the crossover between parallel tracks. The trolley wire of the turnout is connected to the main wire by means of a frog. In order to prevent the collector bow on a locomotive, entering from the turnout, from catching in the angle at the frog, radiating deflector wires are placed in the angles between the two trolley wires. These deflectors are carried by yokes screwed to the trolley wires and by yokes fastened to the catenary hangers. They slope up at each end, so that the collector shoe cannot pass over them.

FEEDER - PASS WIRES.—The feeders or pass wires which are supported on the inner insulators of the lower bracket arm on the bridges are looped into the bus-bars on each alternate anchor bridge. These connections are made through circuit-breakers, so that in case of the

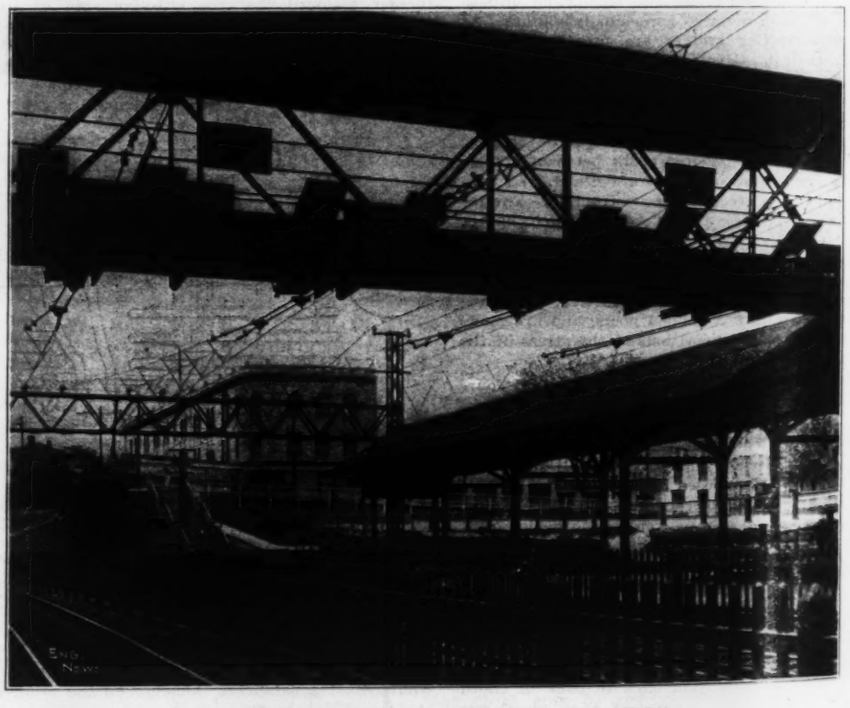


FIG. 6. LOW BRIDGE OVERHEAD CONSTRUCTION.

grounding of the bus-bar structure of any anchor bridge one of the auxiliary feeders will pass around the grounded bridge to the next section beyond. On each anchor bridge one pass wire is broken by a strain insulator, and connections are made through circuit-breakers to the bus-bar. The other pass-feeder is carried directly through, and a single tap connection is made from the feeder through the circuit-breaker to the bus-bar. Upon the next bridge these conditions are reversed, so that each pass-feeder is divided into four-mile sections. This arrangement provides a maximum flexibility of control. This scheme is shown in the diagram, Fig. 8, which shows the operating scheme simplified.

ELECTRIC LOCOMOTIVES.*

It was found that the common load of a New Haven locomotive is a 210-ton train; consequently the locomotives were designed to meet this demand. The fewer trains in local service of 210 to 630 tons weight, will be run by two or three locomotives in multiple, one single engine driver controlling all exactly as a single unit. The specifications require that each unit locomotive shall be able to haul a 200-ton train at a speed of 65 to 70 mi. per hr., and a 250-ton train at 60 mi. per hr.

During the trial tests the locomotives used traveled over 16,000 miles with no indication of a necessary change in the design of the tractive apparatus, and it is confidently believed that the commercial service will show the operating conditions to have been so well anticipated that revision will be needed only in the most subordinate and minor details.

The mechanical parts were built by the Baldwin Locomotive Works from designs developed by the cooperation of the engineers of the Westinghouse and New Haven companies.

The locomotive body is carried on two four-wheel trucks, each wheel of which is a driver. This is an entirely different method from that employed on the New York Central type, where it will be remembered the body is supported by a single rigid four-wheel truck, with a small guide truck at each end of the locomotive. A comparison of the New Haven and New York Central types may be obtained from the accompanying table and from a similar table in the article, previously mentioned, on the New York Central installation.

MOUNTING OF MOTOR.—Mechanically considered, the motors are of the gearless type, and interest in the equipment is naturally centered in the methods employed for suspending the motors and for transmitting the torque to the drivers. Special precautions are taken to insure that both the gravitational force of the motor on the axle and the torsional force of the armature on the drivers are transmitted through elastic media, on account of the destructive effect which the great weight of the motor equipment would otherwise produce on the track at high speeds.

The hollow shaft of the armature is constructed in two halves. These two halves are alike, and each is provided with an end disk from which project seven hollow pins. Each half is forced by hydraulic pressure into the ends of the hollow armature spider, and is securely keyed in place. The armature and quills are mounted on the locomotive axle. The split housings at each end of the armature carry the armature bearings and are rigidly clamped to the outer field frame of the motor.

The axle of the locomotive passes through the armature quill, and when actually concentric with it there is a clearance of about ⅝-in. on all sides between the axle and the inside of the shaft. This allows a slight movement of the armature in respect to the axle, required by the flexible suspension of the motor which is about to be described.

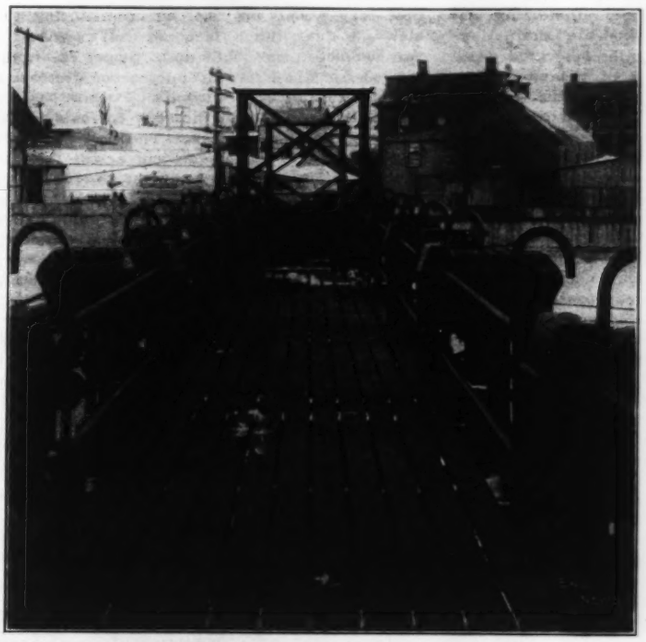


FIG. 7. VIEW OF DECK OF ANCHOR BRIDGE.

On each end of the locomotive axle is mounted a 62-in. driving wheel, in the hub of which are formed seven circular pockets, into each of which there projects one of the hollow pins on the end of the armature shaft. Each pin is surrounded by a spring placed between the outer circumference of the pin and the inner circumference of the pocket. This spring is arranged so as to tend to hold the pin concentric with the pocket, and it resists yieldingly to any gravitational or torsional force for a total movement of ¾-in. The spring is of unusual form; its turns are progressively eccentric. The convolution of the spring first touches the outer circumference and then passes inward and gradually approaches the inner circumference, which is reached by the end of the second turn; it then gradually passes from the inner to the outer circumference, which latter is reached at the end of the fourth turn and so on to the end of the spring. Between the outer circumference of the spring and the inner circumference of the pocket is fitted a sheet iron tube, and a similar tube is placed between the spring and the pin. These tubes and the spring form a unit which may be taken intact from the pocket when the outer end cap is removed. On account of their mechanical form and their position in the pockets these springs cannot be stretched beyond their elastic limit, and, since each pocket is provided with adequate lubrication, it is expected that they will withstand the most severe wear and last indefinitely. They are capable of sustaining the whole weight of the motor, but they will normally be used solely for transmitting the torque to the drivers. Each pin contains a hollow space in which is placed an additional spring which serves for receiving the end thrust of the motor against the drivers.

The weight of the motor is carried by the truck by providing a steel frame entirely distinct from the truck and pivoted from the journal boxes of each locomotive axle. From this frame the weight of the motor is carried by springs on which rest lugs of the field structure. The adjustment of the tension on these springs determines what portion of the weight of the motor is carried by them and just how much weight is carried through the pins on the armature quill. The backward torque of the structure is transmitted to the truck through rods which permit a certain amount of vertical motion in the motor.

MOTOR ARMATURE.—The active winding is a direct-current type, closed on itself and connected to the commutator through the preventive leads which are a feature of the Westinghouse design of single-phase motor. These leads serve the same function as preventive coils used in alternating-current work when passing from one tap to another of a transformer. The armature windings consist of several coils per slot with a single turn per coil. The coils are form-wound and inserted in the slot from the top.

The brushes and brush-holders resemble very closely those on direct-current motors. There are several carbon brushes per holder, each brush having a thickness of ⅜-in.

MOTOR FIELD.—The winding is of the compensated type, reaction arranged in two circuits: the main field coils and the compensating field coils, the latter of which are placed in slots in the pole faces and neutralize the reaction of the armature. Each pole is provided with a number of slots for containing the neutralizing coils, which remain at all times electrically in series in the armature circuit, whether the machine is operated by direct current or alternating current. The neutralizing coils are mechanically so arranged on the core that the active field coils can be removed without disturbing the other coils. Although during normal direct-current operation the field coils receive twice as much current per armature ampere as during alternating-current, and therefore, in effect, the coils of each motor are arranged in two groups which are placed in series for direct and in parallel for alternating current, the active field coils for each motor are in reality joined permanently in series and only two leads pass from the field frame for this purpose. Two motors are operated as a unit, and

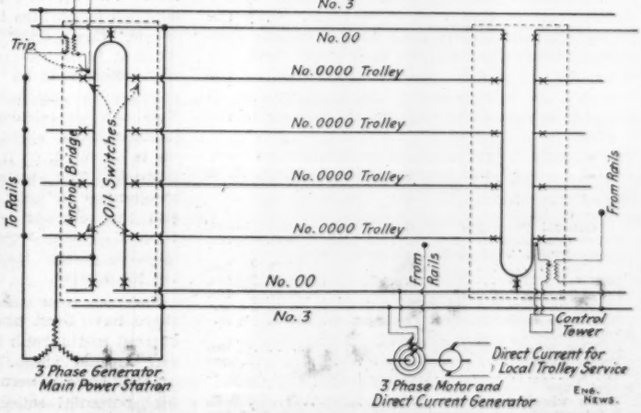


FIG. 8. DIAGRAM SHOWING THE GENERAL SCHEME OF POWER TRANSMISSION AND LINE CONTROL. NEW YORK, NEW HAVEN & HARTFORD R. R.

*The first locomotives built by the Westinghouse Co. for the New Haven system were described in Engineering News March 22, 1906. Details there given are not hereinrepeated except very briefly.

the separate field circuits of these motors are placed in series or in parallel as desired, according to the current used.

As has been intimated, the armatures on each truck, with their corresponding compensating field coils, are joined permanently in series and are operated at all times as a unit. For direct-current work the two motor units of each locomotive are connected in series at starting and in parallel at full speed, while for alternating-current work the two units are operated separately from the secondaries of the step-down transformers at variable voltage, so that they are practically joined in parallel at all times. Although during direct-current operation the familiar series-parallel method of control is employed, several unusual features have been introduced, so that the losses during acceleration are equally as small as, and perhaps smaller than, would be the case if there were complete series-paralleling of the four motors by the method used ordinarily by four-motor equipment. The motors being of the compensated type will run sparklessly with the fields weakened to any desired extent, and this condition is taken advantage of during the acceleration period before passing from the series to the parallel position. Thus there is eliminated a large portion of the loss which would take place in the resistance if the motors were changed directly from the normal series position without resistance to the parallel position with the full resistance in circuit. Much of the lower part of the normal speed range in the parallel position is covered by the motors connected in series with shunted field coils. The acceleration is extremely smooth, which condition is to be attributed partly to the facts just stated and partly to the fact that in passing from the series to the parallel connection the circuit to neither motor is opened, nor is either motor short-circuited. In the initial series position at starting one motor unit is connected to the ground side and the other to the trolley side, with the resistance in series between them. In the final series position the resistance is out of circuit and two united are in series across the line. If, now, there be connected in parallel with each motor unit a resistance of a value such that one-half of the line voltage will cause to flow through it a current equal in value to that passing through each motor, the two motor units will in effect be connected in parallel across the line, each unit having in series with it a resistance which absorbs one-half the line voltage. Under this condition no current will flow directly through the middle-voltage connection between the two motor units, and this connection may be broken without changing the performance of the motors, after which the resistance in series with each motor may be decreased until the two units are directly in parallel across the line.

Each running point for the motors is obtained from the transformers through a series of three preventive coils. These preventive coils are essentially small step-down transformers, having a transforming ratio of two to one. Two of the coils have their outer terminals connected through unit switches to the transformer, and the third coil is connected permanently to the center terminals of the other two, while its middle terminal supplies the current to the motors. It will be seen that the capacity of the unit switches on the transformer is only one-fourth what would be required were only one step used at a time.

During alternating-current operation each motor unit is fed at variable voltage from the secondary of a step-down transformer, there being two separate and distinct transformers on each locomotive. There were two objects in using two, rather than one main transformer: first, to effect the convenient disposal of the weight of the transformers on the locomotive; second, to secure increased reliability of service in case a transformer circuit should be disabled.

The same master controllers are used for alternating current as for direct current. Each switch used in the motor circuits is of the Westinghouse "unit" type operated by air under 80 lbs. pressure, and controlled by an electromagnet which receives current from a 20-volt storage battery.

The unit switches differ inappreciably from those used in ordinary direct-current work. They are arranged in groups for convenience, and the switches of each group have their magnetic blow-out coils placed in the same line, so that they assist one another in producing the blow-out flux. Each blow-out coil consists of two complete turns, built up of copper sheets insulated by japan for the purpose of decreasing the losses from eddy currents. Precautions are also taken to minimize the eddy currents in the iron cores of the magnets. The pole faces are not laminated, but slots are cut across them in such direction as to prevent the production of excessive eddy currents.

There are, therefore, on the locomotive, three systems of wiring: the 11,000-volt primary circuits to the step-down transformers; the lower-voltage motor circuits (the secondary circuits from the transformers and the equivalent 600-volt direct-current circuits), and the battery electromagnet circuits. The high-potential circuits pass directly from the trolleys through a manually-operated oil switch to one terminal of the primary of each of the step-down transformers, the other terminals of which are effectively grounded to the locomotive frame. The lead from the trolleys to the oil switch is protected by a grounded covering, which eliminates danger to life from contact with these leads. Only the 20-volt battery circuit runs to the master controller. The motor circuits pass either from the direct-current trolley, the third-rail shoe or the taps on the secondaries of the transformers to the unit switches and through the motors to the ground.

MULTIPLE OPERATION. — The locomotive may be controlled from either end by means of a master controller, which is of the usual type, except that its handle is somewhat different from those heretofore used, resembling somewhat the throttle lever of a steam locomotive. No gears are used, the handle being connected directly to the drum shaft. The reverse lever is mounted immediately below the operating lever of the controller. The circuits which run to the master controller are directly in multiple with those to the other controller. A continuation of these circuits through flexible leads from one locomotive to another allows any number of locomotives to be operated simultaneously from one master controller. When the master controller is in the off position connections are so established that all circuit-breaker trips which may be open may be closed by the simple pressing of a small push-button on top of the controller.

Current is supplied to the control circuits by two sets of 10-cell storage cells, each of 40 amp. capacity. In connection with the switch groups, cut-out switches are provided so that either pair of motors may be cut out by simply rendering certain switches inoperative. It is thus possible to cut out the motors without manipulating the main circuit.

CURRENT COLLECTORS. — There are two pantagraph bow frames for collecting the current from the 11,000-volt overhead conductor system. The upward pressure against the wire is supplied by springs in the base of the pantagraph frame. Compressed air is admitted to a cylinder when it is desired to lower the collector. When the collector is in its lowest position a catch engages the mechanism and holds it in place. This can be released by means of an electro-pneumatically operated lever when compressed air is on hand, or it can be released manually if desired. The framework of the pantagraph mechanism is built up of steel bicycle tubing, and the collector bow is a broad strip of soft copper. The collector mechanism is mounted on massive molded insulators bolted to the roof of the locomotive.

For use over the New York Central tracks there have been provided both a second direct-current pantagraph trolley and a system of third-rail contact shoes. The direct-current bow is of the same general type as that used by the high-potential collectors, and it is mounted immediately over the center of the locomotive. There are two mechanically-separated but electrically-interconnected contact shoes on each side of each truck, making a total of eight shoes per locomotive. These shoes are designed for use with either an overrunning or an underrunning rail, and the mechanical pressure, in each case, is supplied by springs. On account of the fact that no third rail will be used over the high-potential portion of the route, and the projecting shoes in their normal position would be liable to strike any small obstruction along the side paths,

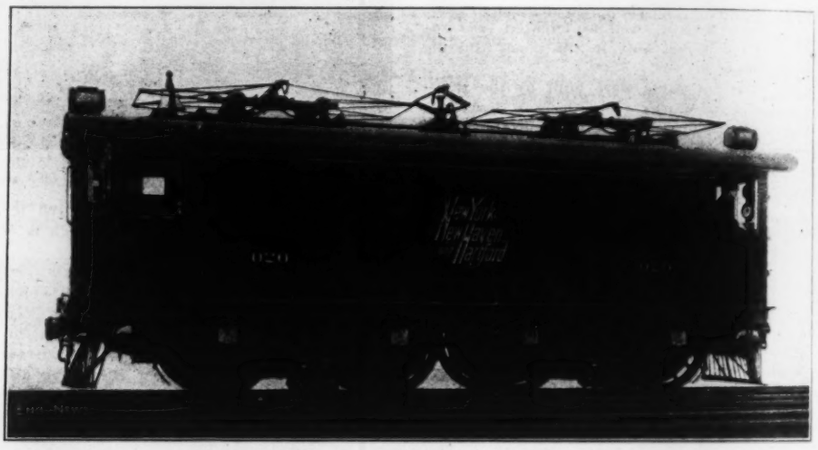


FIG. 9. LATEST TYPE OF SINGLE PHASE ELECTRIC LOCOMOTIVE, NEW YORK, NEW HAVEN & HARTFORD R. R.

TABLE I.—ELECTRIC LOCOMOTIVE, N. Y., N. H. & H. R. R.*

General Dimensions:	
Class of traffic—	General Passenger; Express; Local Express; Local.
Gage (standard)	4 ft. 8½ ins.
Total length over buffer platform (one unit)	28 ft. 4 ins.
Extreme width	9 ft. 7½ ins.
Height to top of cab	12 ft. 2 ins.
Height to collector (pantagraph closed)	14 ft. 1 in.
Height to collector (pantagraph open)	24 ft. ½ in.
Running Gear:	
Driving wheels, number, 8; Diameter	62 ins.
Truck wheels	none
Trucks	14 ft. 6 ins., c. to c.
Wheel Base:	
Truck wheel-base	8 ft.
Total wheel-base	22 ft. 6 ins.
Weight:	
Total (all on drivers)	93 tons
Motive Power:	
Supply	600 volts, D.C. / 25 cycles, 11,000 volts, A.C.
Conductors	trolley; caternary construction
Motors	4 Westinghouse, 250 HP.
HP. locomotive	1,000 (1 hr. rating)
Normal full-load current, 77 amp.; power factor, 85%	
Draw-bar pull	20,000 maximum. / 5,000 lbs. at 60 min. per. hr.
Speed with 250-ton train on level	60 mi. per hr.
Control	Series parallel on D. C. / Variable voltage on A.C.

*Many of the figures herein presented are compiled from a paper by Mr. B. G. Lamme, Engineering News, Mar. 22, 1906.

a device is used for lifting the contact-shoes out of the way when the locomotive is using alternating current. This device will be operated electro-pneumatically and will be automatic, so that when the alternating-current circuit is completed the shoes will be lifted from the rails.

AUXILIARY APPARATUS.—All of the controlling mechanism of the locomotive is placed within the cab. In addition to the various switch groups and the two main transformers referred to above, the cab contains two air-compressors driven by compensated motors of the same general type as the main driving motors. The circuits to these motors are controlled automatically by the pressure of the air in the main reservoirs, which are located underneath the locomotive. The four main traction motors, the high-potential transformers and the main-circuit rheostats are cooled by air furnished at low pressure by means of two motor-driven centrifugal blowers which draw air through openings in the cab. The low-pressure air has two paths. One path passes first through the transformer and then to the rheostat. The other path goes directly to the motors. It enters the armature near the shaft, passes around and between the armature laminations, flows outward through the ventilating ducts in the field cores, and reaches the outer air through perforated caps on the frame of the motor. Since a considerable volume of air is required for each motor, and it is undesirable to cause the air to assume a high velocity, it was necessary to provide a large flexible conduit between the air passages on the cab and those on the motors proper. The flexible conduit is made up of heavy canvas tubing, which is reinforced with wire and given an accordeon pleating. By the use of the air blast the temperature of the motors under load has been so decreased that the continuous rating is almost equal to the one-hour rating.

COS COB POWER STATION.

The power-house at Cos Cob, three miles west of Stamford, is on the Mianus River, about a mile from Long Island Sound. The location is such that the coal can be delivered either by land or water, and an unlimited amount of salt water for condensing purposes is available from the Mianus River. By the erection of a dam in this river, at a point about a mile up-stream from the power-house, an abundant supply of exceptionally pure boiler feed-water is also readily obtained.

BUILDING.—The general style of architecture of the power-house building is Spanish Mission. The walls are constructed of plain-faced concrete blocks, the color of which forms a pleasing contrast with the red Spanish tile roof.

The entire area of the site selected was practically solid rock, with but a few inches of earth above it, and necessitated blasting the excavation for the basement and the condenser intake and discharge.

The material excavated was a gneiss rock, which proved excellent for concrete aggregate; furnishing, after crushing and screening, all the broken stone required for the building, and a sufficient quantity of crusher screenings in lieu of sand for the concrete of the exterior walls. The building walls, below the water table, and the machinery foundations are monolithic concrete. The water table and the walls above it, including the window arches and coping, are of concrete blocks. Below the water table the exposed surfaces of the walls have a "bush-hammered" finish. The interior columns in the boiler-room are of structural steel, but all other columns required in the building are of concrete blocks. The steel roof trusses over the turbine-room are supported on concrete-block pilasters, formed in the building walls, while over the boiler-room they are carried by the pilastered building walls and by the interior steel columns, which also support the boilers, the mechanical draft equipment and the stack. The front of the switchboard gallery, at the south end of the turbine-room, is carried on concrete-block columns, which also support a reinforced-concrete girder forming one of the crane runways. The other crane runway is formed by another reinforced-concrete girder, built into the partition wall between the engine-room and boiler-room, and is supported upon pilasters formed in this wall. The column footings below the engine-room and boiler-room floors are of monolithic concrete. The basement floor is of concrete laid upon the foundation rock. All other floors in the building are of reinforced concrete; and the roof, which has a pitch of 4½ ins. per ft., is of reinforced cinder concrete, finished on the exterior with Ludowici tile.

A self-supporting steel stack, 13 ft. 6 ins. in diameter, extending to a height of 100 ft. from the engine-room floor, is carried by the steel columns which support the fan-room floor, leaving the space below, on the boiler-room floor, entirely clear.

The turbine-room is 60 ft. wide by 112 ft. long, and the switchboard occupies an additional space 25 ft. wide by 110 ft. long. The boiler-room is 160 ft. long by 110 ft. wide. The general arrangement of turbines, boilers, etc., is shown in the floor plan, Fig. 10. The distance from the floor to the top of the crane runway rail is but 27 ft. 2 ins., which low headroom is made possible by the use of horizontal turbines; the height from the turbine-room floor to the bottom of the roof trusses is but 39 ft. 2 ins. The interior walls of the engine-room are finished with a 6-ft. wainscoting of Faience tile. The turbine-room is equipped with an electric traveling crane, provided with two 37½-ton trolleys operated from the exciter circuit.

TURBO-GENERATORS.—The initial generating equipment of the power-house consists of three multiple-expansion parallel-flow Parsons steam turbines direct-connected to three-phase Westinghouse generators. Provision has been made for the installation of a fourth unit of corresponding size. The turbines are rated at 4,500 brake HP. each, and the generators at 3,000 KW. each, at 80% power factor, or 3,600 KVA.

The turbines are operated at 1,500 r. p. m. by steam at 200 lbs. pressure and 100° superheat. The continuous overload capacity of the units is 50%. Momentary overloads of 100% can be taken care of when operating condensing. The turbines are equipped with the latest accessories in the way of automatic safety stops, water-packed glands for the turbine shaft, and adjustable

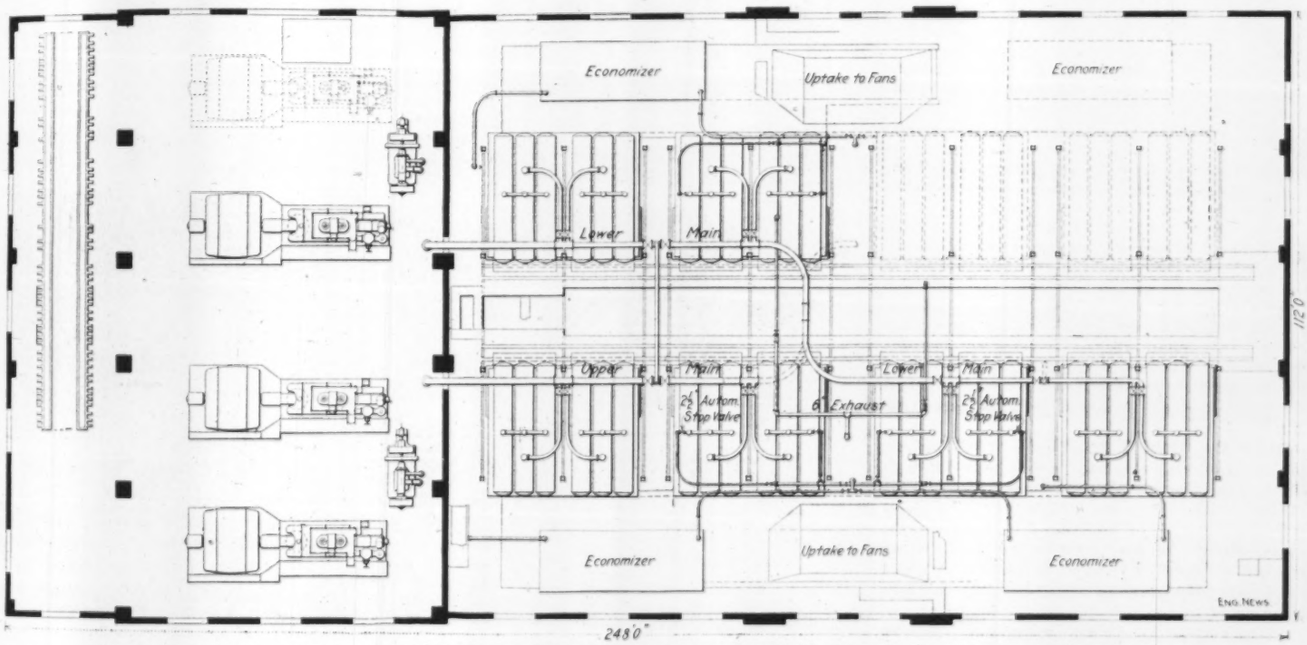


FIG. 10. FLOOR PLAN COS COB POWER STATION, SHOWING RELATIVE ARRANGEMENT OF BOILERS AND TURBINE UNITS.

water-cooled, bearings provided with a continuous-circulation oiling system.

The generators are entirely enclosed by a casing into which air is drawn through suitable ducts from a fresh-air chamber under the switchboard gallery, and from which the air is discharged through other ducts into the basement. This system of generator ventilation renders the operation of the generators practically noiseless.

The excitation of the generator fields is provided for by two 125-KW. direct-current generators, direct-connected to Westinghouse engines, and by one motor-driven exciter.

A separate condensing outfit is provided for each turbine, consisting of an Alberger three-phase counter-current surface condenser; a two-stage dry air pump; a centrifugal circulating pump direct-connected to a Westinghouse engine; and a Monitor hot-well pump, the speed of which is automatically controlled by a float.

Condensing water for all the condensers is furnished by a single flume, which is constructed of timber having a lining of creosoted lumber, from the intake at the face of the dock to the shore line, and of concrete for the remainder of its length to and under the generator-room. A discharge flume of similar construction parallels the intake flume under the turbine-room, and

then diverging from it discharges the condensing water into the river. Each condenser is installed directly beneath the corresponding turbine, and over the discharge flume, while the circulating pumps are located over the intake flume, thus making all the connections as short as possible.

The pipes leading from the condenser to the discharge flume have a submerged discharge, thus decreasing the head under which the circulating pumps work.

To prevent the rapid deterioration of the brass condenser tubes by the electrolysis which usually occurs where salt water is employed for condensing purposes, and which is often aggravated by stray currents passing through the water pipes into the station and from thence to the condensers and out through the pipes leading into the intake and discharge flumes, a motor-generator set has been installed and provided with suitable controlling apparatus for maintaining in each condenser a counter electromotive force slightly in excess of the electromotive force due to electrochemical action and stray currents.

BOILER PLANT.—The initial boiler installation consists of twelve 525-HP. Babcock & Wilcox water-tube boilers set in batteries of two boilers each, and arranged with eight boilers on one side and four boilers on the other side of the boiler room, separated by a 21-ft. firing floor. Provision is made for four additional boilers to take care of the fourth turbo-generator unit when installed. These boilers are equipped with Roney mechanical stokers and Babcock & Wilcox superheaters and deliver steam at 200 lbs. gage pressure and 125° superheat. A novel feature of the boiler settings is the installation of an external steel casing entirely enclosing the brickwork, thus rendering the settings impervious to air leaks.

Three Green fuel economizers are provided. The boiler flues leading to the economizers are arranged with by-passes so that one or all of the economizers can be cut out, and the flue gases from either two or four batteries may be passed through either one or two of the economizers, thus adapting the economizer installation to the changing demand upon the boilers. The economizers are enclosed by means of metal sectional covering insulated with prepared asbestos blocks.

INDUCED-DRAFT SYSTEM.—After leaving the economizers, the flue gases pass through sheet iron flues to the fan chamber over the center of the boiler room. Here four 14-ft. fans, direct-connected to horizontal high-speed engines, deliver the flue gases to the stack, which is only of sufficient height to carry the gases away from the building. The speed of the fans is adjusted to the demand on the boiler by automatic regulating valves controlling the fan engines.

COAL-HANDLING INSTALLATION. — All coal received by water is unloaded from the barges by a steel derrick operating a clam-shell bucket and is delivered into a hopper of 15 tons capacity at a height of 55 ft. above the dock. This bucket is operated by an engine on the dock, supplied with steam from the power-house. From this hopper the coal is fed by gravity into a coal crusher and from the crusher it drops into steel cars, where it is weighed. The cars are then drawn by cable up an inclined single-track railway of 13% grade and into the boiler room through an opening near the roof. This track is supported upon structural steel towers, and is designed so that two cars can be operated upon it, passing each other through an automatic turnout at the center. The cars discharge the coal into a hopper, from which it is delivered into two flight conveyors, extending the length of the boiler room. Openings in the bottom of the conveyors discharge the coal into spouts leading to the stoker hoppers of the boilers. The capacity of the conveyors is in excess of the amount of coal required to operate the boilers, and the surplus coal is discharged at the further end of the boiler room into a concrete storage bin below the boiler room floor.

Coal received by rail is dumped from the car directly into a chute leading to this same storage bin. When the boilers are to be supplied from this source the coal is discharged from the bin by gravity into a coal crusher, and thence into a bucket conveyor located in a tunnel underneath the bin, by which it is delivered to the conveyors above the boilers, and thence through the chutes to the stoker hoppers.

The cable railway and the flight and bucket conveyor are operated by three-phase induction motors taking current from the "Station Service" Line. The ashes are dumped from the dumping grates of the stokers into chutes leading to narrow-gage cars in the basement, by which they are at present carried to the low ground in the neighborhood of the power-house and used for filling.

FEED-WATER SYSTEM.—Under ordinary conditions the boiler feed-water is delivered from the pump house at Mianus through a 10-in. main to a concrete reservoir of 600,000-gal. capacity situated just outside the power-house. From this reservoir the water flows by gravity to two 13,000-gal. feed-water tanks located in the boiler-room basement. These tanks also receive the discharge from the hot-well pumps. The water is then drawn from these tanks by the feed pumps and delivered through the feed-water heaters and the economizers into the boilers.

The pumping equipment at Mianus comprises two single-acting vertical triplex plunger pumps, geared to Westinghouse three-phase motors.

FIG. 11. VIEW OF COS COB POWER HOUSE, SHOWING COAL HANDLING FACILITIES.

One of these is of sufficient capacity to meet the requirements of the plant running non-condensing and the other when running condensing. These pumps are operated by current obtained from the power-house.

An auxiliary source of feed-water supply is provided for by a connection to the mains of the Greenwich Water Co. Provision is made for connecting either source of feed-water supply direct to the suction side of the feed-water pumps, and also for by-passing the feed-water heater or the economizers. An emergency feed-water supply system is also provided, consisting of two Hancock inspirators, taking water from either source of supply and delivering it through an independent line to the boilers.

PIPING.—A steam main is carried over the boilers on each side of the boiler house, each of the two mains crossing over to the opposite side at the center of the boiler room. Provision is made for cross-connecting these two mains. From the boiler room, the mains extend through the partition wall into the turbine room, thence downward into the basement connecting to a header under the floor. From this header connections are made to each turbine. In addition to the throttle valves and automatic stop valves, shut-off valves are provided for each turbine under the boiler-room floor. These valves are controlled by hand wheels mounted on stands in the turbine room. A separate steam main is provided for the steam-driven auxiliaries, which are all designed to use superheated steam. Steel pipe with extra heavy welded flanged joints is used for all high-pressure steam lines, contraction and expansion being provided for by the use of long radius bends. An exhaust line leads from each turbine directly down to its co[ndenser] is connected by an automatic relief [valve] to an individual exhaust line which pas[ses] through the engine room basement to the ou[tside] of the building and thence to a point abo[ve] the roof. The piping from the pumps to the [feed-water] heaters and economizers is of cast [iron], while that from the economizers to the b[oilers], with the exception of a cast-iron header [below] the floor, is of brass.

A closed feed-water heater cont[aining] 2,000 sq. ft. of surface and utilizing the ex[haust] from the steam-driven auxiliaries is provi[ded].

ART-CLEANING SYSTEM. — F[or] cleaning generators, switches, etc., compressed [air] is furnished throughout the engine room a[nd] switchboard gallery from a Westinghouse [No.] Brake Co.'s locomotive type of air compress[or] supplying air at 100 lbs. pressure.

The drips from the high-pressure steam line are returned to the boilers by a Hol[ly] gravity return system, the receiver of which is located in the engine room basement, and the discharge chamber at the highest point of the boiler room.

MACHINE SHOP.—A large room in the basement of the boiler room has been furnished with a full machine equipment of lathes, shapers, drill presses, planers, etc., for general repairs. The machinery is driven from an overhead line shaft operated by an induction motor.

Separate toilet-rooms are provided in the basement for fire-room and engine-room forces, each containing individual lockers, shower baths, wash basins, etc. There is provided, of course, the necessary equipment of service, fire and oil pumps.

ELECTRICAL DISTRIBUTION. — The main cables from each generator are run in the air chamber under the turbine-room floor, up to the switchboard gallery and thence through oil-circuit breakers down to the high-tension buses under the switchboard gallery. These circuit breakers are electrically interlocked so that the buses cannot be paralleled.

The two high-tension buses, with their accompanying switching equipment, are interchangeable, and are arranged so that each can be used separately; one supplies three-phase current to the feeders running to the Port Morris power station of the New York Central, and the other supplies, principally, single-phase current for propulsion. Each bus is further divided by knife switches into three sections; each end section containing generator leads and propulsion feeders, and the center section containing the Port Morris feeders, so that in an emergency a still further subdivision can be effected.

When a bus section or the entire bus is used for supplying single-phase propulsion current, one leg is grounded directly to the track rails of the right-of-way through suitable switches; another leg supplies the outgoing feeders which are run in duplicate, connecting directly to the trolley; the third leg of this bus is also connected to a feeder which is carried along the right-of-way for the purpose of supplying power for local purposes, and completing the three-phase circuit along the line. This is shown in the diagram,

Fig. 8. Each leg of the high-tension bus, consisting of two 3 × ¼-in. copper bars, is enclosed in a separate masonry compartment composed of pressed brick and soapstone, and is supported on porcelain pillars and bushings projecting from the side wall of the compartment, the bushings providing for cable connections to the bus. Removable glass doors are provided in the bus compartments at small openings opposite all connections and supports. The connections between the bus bars and the circuit breakers consist of insulated cable and are carried up in separate brick septums on the back of the bus-bar and oil-circuit breaker structure. Each oil circuit breaker can be disconnected from the bus and circuit by hook-type knife switches located on the rear of the structure.

The feeder cables pass along the top of the circuit-breaker structure, thence to choke coils in the arrester gallery and through special windows to the line. Each feeder is protected by a lightning arrester of the Westinghouse Electric & Mfg. Co.'s low equivalent type, with fuses.

For normal operation of this station one set of buses will supply the three-phase feeders leading to Port Morris, and the other set the single-phase propulsion feeders and the local three-phase circuits.

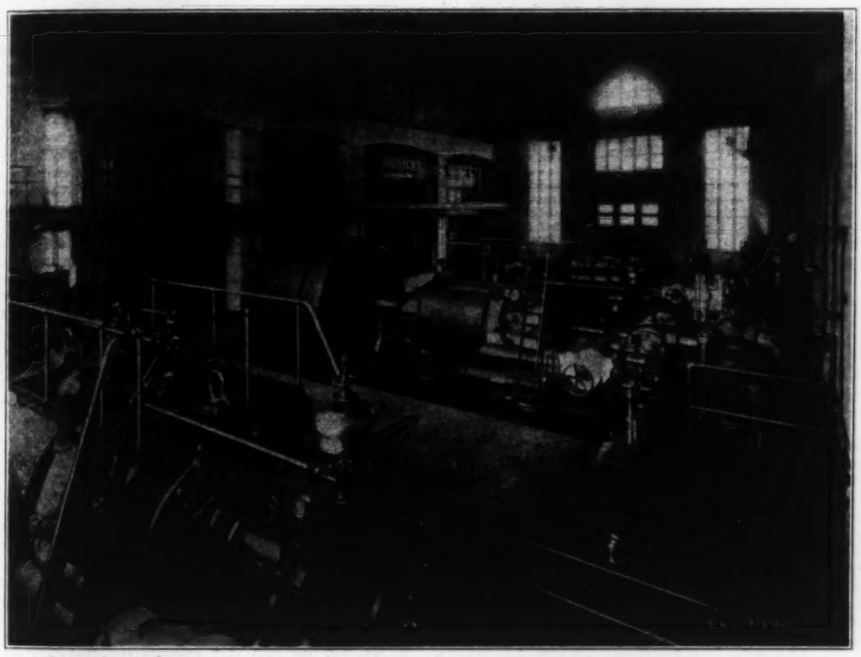


FIG. 12. TURBINE ROOM, COS COB POWER STATION.

SWITCHBOARD.—The main switchboard contains four panels for the operation of the generators, three panels for the control of the exciters, two panels for the Tirrill regulators, one load panel, one inclined station panel for the synchroscope and A. C. voltmeters, and five panels for the apparatus controlling the outgoing feeder system and the local high-tension circuits.

Each generator panel is equipped with the usual instruments indicating current, power factor, power, and field current. Receptacles are also provided on each generator panel for making connections with the synchroscope and the voltmeters on the inclined panel. This panel contains the main field switch and rheostat hand wheel, together with an electric governor controller for changing the speed of the generators from the switchboard gallery for the purpose of synchronizing, when it is desired to throw two or more generators in parallel. The oil circuit-breakers between the generator and the buses are also electrically controlled from these panels.

For the control of the station circuits a local-service switchboard is installed, containing apparatus for controlling the motor of a motor-driven exciter, the station lighting circuit, the power circuit and the storage battery circuit. The storage battery is located in the basement below the switchboard gallery, and consists of 55 cells, Westinghouse type, of 10 amperes capacity for 8 hrs. and is used for operating the control circuits of the circuit breakers and the switchboard signal lights. The battery is charged through a Cooper-Hewitt mercury converter, taking current from the alternating current lighting circuit.

LIGHTING.—The building is lighted in the day time by large windows (Fig. 11), glazed with wire glass set in cast iron sash. A monitor, with windows for light and ventilation, extends lengthwise over the boiler room. Cooper-Hewitt mercury lamps are used for general night illumination and incandescent lamps for restricted areas. Direct current for these lamps is supplied by a motor-generator delivering current at 115 volts.

The administration and general supervision of the entire electrification project has been in the hands of Mr. E. H. McHenry, M. Am. Soc. C. E., Vice-President of the New York, New Haven & Hartford R. R. The difficult task of determining and analyzing the operating conditions and requirements was assigned to Mr. Calvert Townley, Assoc. Am. Inst. E. E., Consulting Engineer, and to Mr. W. S. Murray, M. Am. Inst. E. E., Electrical Engineer, by whom design and execution have been carried out. The contractor for the locomotives, overhead construction and turbo-generators was the Westinghouse Electric & Manufacturing Co. The contractor for the Cos Cob power-house and equipment was Westinghouse, Church, Kerr & Co.

LAKE MICHIGAN WATER FOR GRAND RAPIDS has again been made the subject of an engineering report, this time by Mr. John W. Alvord, M. Am. Soc. C. E., Hartford Building, Chicago. Mr. Alvord estimates the cost of supply from this source as $2,470,000, or $285,000 less if electrically operated pumps are used. The main item in Mr. Alvord's estimate is $1,332,000 for a force main. An earlier estimate for water from Lake Michigan, made by Messrs. Allen Hazen, M. Am. Soc. C. E., New York City, and Samuel M. Gray, M. Am. Soc. C. E., Providence, R. I., involved an outlay of $3,363,000, of which $2,212,000 was for a 60-in. steel force main. Mr. Alvord's plan contemplates a 48-in. main. The voters of Grand Rapids authorized last April the introduction of water from Lake Michigan at an approximate estimated cost of $1,600,000. An alternative plan for a water supply for Grand Rapids involves the purification of water from a nearby source by means of mechanical filtration.

COURT DECISION AGAINST THE POLLUTION OF A BROOK IN DRACUT, MASS., BY THE AMERICAN WOOLEN CO.

A sweeping court decision regarding the discharge of wastes from a woolen mill into a small stream has recently been rendered by the Massachusetts State Supreme Court. In explanation of some points not brought out in the decision (this being a decision on appeal), the following facts may be given.

The case in question was brought by Mr. Percy Parker, of Lowell, Mass., a riparian owner and owner of a paper mill on Beaver Brook, below the mill of the American Woolen Co. Beaver Brook is a tributary of the Merrimac River. The following statement regarding the brook was made by the Massachusetts State Board of Health in December, 1899, in response to an application from the city of Lowell in the matter of possible future sources of water supply:

Beaver Brook, above the village of Collinsville, drains an area of about 88 sq. mi., nearly all of which lies within the limits of the State of New Hampshire. The watershed contains the towns of Derry, Londonderry, Windham and Pelham, and portions of other towns in New Hampshire. This source would furnish sufficient water for Lowell; but the water is now polluted by sewage discharged directly into the stream or its tributaries, and it would be impracticable for the city of Lowell to prevent the pollution of this stream in New Hampshire.

Under the circumstances, Beaver Brook would not, in the opinion of the Board, be a suitable source of water supply for the city.

Of the towns named in the above quotation, Derry, N. H., has a sewerage system which discharges directly into the brook. An outbreak of typhoid fever in the village of Collinsville, a part of the town of Dracut, in 1899 led to an investigation by the State Board of Health. In its report on the outbreak, the board stated that the typhoid was probably due to "the polluted condition of the water supply of the American Woolen Co." in the village of Collinsville. Acting upon the advice of the board, a new source of supply was subsequently adopted.

Full cognizance of some of the facts stated above does not appear to have been taken by the court in its decision, in view of the statements toward the end of the decision to the effect that the water of the stream above the mill is of a quality satisfactory for a domestic supply. The court also holds that the trade wastes from the mill can readily be treated so they will be of satisfactory quality to discharge into a potable water supply. We understand that representatives of the American Woolen Co. hold that the decision of the court is unreasonable in view of all the circumstances in the case, and that such a ruling, if followed elsewhere, would result in shutting down a large proportion of the industrial establishments of the State.

The company is installing works for the treatment of its wastes, with Mr. Wm. S. Johnson, M. Am. Soc. C. E., 101 Tremont St., Boston, as engineer.

The decision follows:

It will be convenient in this case to consider first the questions raised by the plaintiff's exceptions to the master's report and to the ruling of the single justice thereon. That ruling was in substance that one riparian proprietor has no right to discharge into a stream substances which will corrupt and foul the waters thereof to the injury of a lower riparian proprietor; that a reasonable use of the water of a stream by a riparian proprietor does not include the right to make the stream a sewer or to discharge into it such substances and things; and that upon the facts found by the master the plaintiff was entitled to an injunction restraining the defendant from discharging noxious substances into the stream and thereby corrupting its waters and rendering them unfit for drinking and for domestic and other uses. The master on the other hand ruled that the right to discharge waste into a stream and to pollute it, either mechanically or chemically, to a reasonable extent, is one of the incidents to the ownership of land on the banks; that the general principles which govern the abstraction or diversion of water must govern in respect to the deposit of waste matter in a stream resulting from the processes of manufacturing—that is, that a use of the water may be made which is reasonable under all the circumstances of the case; that what constitutes a reasonable use of water in a stream in respect to the deposit of waste matter therein is a question of fact to be deter-

mined from all the circumstances of the case; that every riparian proprietor on a stream has the right to have the water come to him in its natural condition except so far as it is affected by a reasonable use of their property by the owners or riparian proprietors above, and that in determining whether such use of water in a stream with respect to its pollution is reasonable all the circumstances should be considered, and more particularly the size and character of the stream, its condition, volume and rapidity, the density of the population on its banks, the use to which the stream has been, is, and can be applied, the state of improvement of the country in regard to mills and machinery, and the use of water as a propelling power; the established usages of the country in similar cases and the needs, usages and wants of the community, the necessity or importance of the use claimed by the defendant and the extent of the benefit to him as compared with the extent of the injury to the other party. He also ruled that one who is asserting a right which at the time does no damage, but which may operate by long continuance to destroy or diminish the right of the plaintiff, even if that right is not then exercised by the plaintiff and there is no present intention of exercising it, will be restrained by injunction; but that injunction will not be granted to restrain a nuisance when the result would be inequitable.

It is difficult, if not impossible, to reconcile all the decisions which have been made upon the question of the right of riparian proprietors to use the waters of streams flowing through or along their lands. This is a common right, and each must exercise it with all due regard to the rights of others, and each must submit to that degree of inconvenience and hardship in the exercise of his rights which results from the existence of like rights in others. In such cases, each proprietor is entitled to use the stream in such reasonable manner, according to the usages and wants of the community, as will not be inconsistent with a like use by other proprietors above and below him. Cary v. Daniels, 8 Met. 466; Thurber v. Martin, 2 Gray, 294; Gould v. Boston Duck Co., 13 Gray, 442. Many of the decisions relied upon by the defendants are instances of the application of this rule. Pitts v. Lancaster Mills, 13 Met. 156; Springfield v. Harris, 4 Allen, 494; Jones v. Portsmouth Aqueduct, 62 N. H., 488; Snow v. Parsons, 28 Vt., 459; O'Riley v. McChesney, 49 N. Y., 672. Cases in which the proprietors of sawmills have been allowed to throw sawdust and similar refuse into the streams frequently for the reason that the mills practically could not be run unless this was allowed to a reasonable extent, generally have been put upon the same ground. Haskins v. Haskins, 9 Gray, 390; Hayes v. Waldron, 44 N. H., 580; Jacobs v. Allord, 42 Vt., 303; Canfield v. Andrew, 54 Vt., 1; Prentice v. Geiger, 74 N. Y., 341. But permission to do this has been refused where it was found to make the water impure and unfit for drinking and domestic purposes; Lewis v. Stern, 16 Ala., 214; and the tendency of the later decisions is to restrict somewhat the liberality of the original rule. Lockwood Co. v. Lawrence, 77 Me., 297; Canfield v. Andrew, 54 Vt., 1; Red River Roller Mills v. Wright, 30 Minn., 249. And in Canfield v. Andrew, supra, the court is careful to say in its opinion that no one is allowed to deposit any substance in a running stream that will pollute its waters to the injury of a lower riparian proprietor.

It is, of course, true that many of the uses which properly may be made of the water of a natural stream by the upper riparian proprietors will be likely to tend somewhat to defile the water. Sprague v. Dorr, 185 Mass., 10. Its use for watering cattle and for the irrigation of fertilized land, or for bathing or other domestic purposes, will have directly that tendency. Water cannot be made to pass through the propelling machinery of a mill without becoming more or less impure, nor can the water be made available for any manufacturing use without some incidental deterioration of its quality. Surface drainage into the stream will become more and more injurious to the condition of the water as population along its banks grows denser. No one has the right to complain of injury to the quality of water coming from any of these causes. Wells J. in Merrifield v. Worcester, 110 Mass., 216, 219. The natural flow of surface drainage from occupied land or from streets, though much increased by the adoption of sewer systems, so as to materially injure the water of a brook into which it runs, will afford no cause of action to a lower riparian proprietor. Butman v. Newton, 154 Mass., 255. Perhaps the decision in Pennsylvania Coal Co. v. Sanderson, 113 Penn. St., 126, can be justified upon the ground that the injury there complained of resulted in reality from the water pumped from the plaintiff's mine having drained over the surface of the ground into the brook; upon which reason indeed it is partly rested in the opinion of the court. See Crossley v. Lightowler, L. R. 2 Ch., 478.

We regard it, however, as settled that no riparian proprietor has the right to use the water of a natural stream for such purposes or in such a manner as will materially corrupt it to the substantial injury of a lower proprietor, or to cast or discharge into it noxious and deleterious substances which will tend to defile the water and make it unfit for use. This was the doctrine laid down in Wood v. Ward, 3 Exch., 748. It has been maintained in the English courts. Mason v. Hill, 5 B. & A., 1; Pennington v. Brinsop Hall Coal Co., L. R. 20 Eq., 769, 772. It is affirmed in our own decisions. In Merrifield v. Lombard, 13 Allen, 16, it appeared that by the mode in which the defendant had conducted his business a large quantity of poisonous and corrosive substances was permitted to run into a stream, which defiled and corrupted the water to such an extent that the machinery in the plaintiff's mill, lower down on the same stream, was corroded and his use of the water for proper purposes was impaired and prevented: and the defendant was enjoined from continuing so to act, and the court said:

> We know of no rule or principle of law by which such a mode of appropriation of a running stream, in the absence of any proof of a paramount right or title, can be justified or excused as against a riparian owner of land on the same stream below.

In Dwight Printing Co. v. Boston, 122 Mass., 583, it was held that a riparian owner has no right, in the absence of express grant or prescription, to use the waters of a stream for dyeing or printing woolen or cotton cloths in such a way as to pollute the water and render it unfit for drinking purposes. The same doctrine has been incidentally affirmed in other decisions of this court. Washburn & Moen Manuf. Co. v. Worcester, 153 Mass., 494, 497; Walker Ice Co. v. American Steel & Wire Co., 185 Mass., 463, 471; New England Cotton Co. v. Laurel Lake Mills, 190 Mass., 48, 52. There is nothing inconsistent with it in Harris v. Mackintosh, 133 Mass., 228. It has been repeatedly and strongly declared in other states. "Riparian proprietors, mill owners or others have no right to render the water of a stream unwholesome or offensive." Richmond Manuf. Co. v. Atlantic De Laine Co., 10 R. I., 106; Silver Spring Bleaching Co. v. Wanskuck Co., 13 R. I., 611, in which the Court said:

> The right of every owner of land bordering on a stream to the use of the water is well settled; and the fact that he also owns a mill does not lessen his rights. . . . . And he has a right to have the water pass his land in its natural pure state. Bradley v. Warner, 21 R. I., 36; Holsman v. Boiling Spring Bleaching Co., 14 N. J. Eq., 335; Chapman v. Rochester, 110 N. Y., 273; Middlestadt v. Waupaca Starch & Potato Co., 93 Wisc., 1.

In all these cases, it was held that the right of the lower riparian proprietor to the free use and enjoyment of the water of a natural stream extended as well to its quality as to its quantity. And see the cases cited in Gould on Waters, §219; Wood on Nuisances, §427, et seq.; Angess on Water Courses, §136, et seq. The right to use the stream to carry away mere waste matter in a reasonable manner and to a reasonable extent is not so to be extended as to include a right to discharge into the stream noxious and deleterious matter to such an extent as sensibly and materially to foul the water and destroy its purity and fitness to be used by others.

It is true, of course, that there is in any large body of water a purifying principle which will, either by ordinary sedimentary deposit or by chemical change, obviate the evil effects which otherwise would arise from the deposit therein of some limited amount of noxious matter. Accordingly it is not for every small deposit of such matter that the law will give a remedy. This was the case in Brookline v. Mackintosh, 133 Mass., 215. There doubtless must be a material and sensible deterioration of the quality of the water; and this was recognized in the rulings made by the single justice. So in Townsend v. Bell, 167 N. Y., 462, it was found as a fact that the defendant's use of the stream did not render its waters unfit for manufacturing, mechanical or domestic purposes. Merrifield v. Worcester, 110 Mass., 216, was decided on the doctrine that a city is not to be held in damages for having adopted an improper sewerage system.

Nor can we doubt that the plaintiff is entitled to an injunction to restrain the defendant from continuing to pollute the stream, in order to prevent it from gaining a prescriptive right, even though such pollution does not interfere with any use of the water which the plaintiff is now making. Crossley v. Lightowler, L. R. 3 Eq., 279; Pennington v. Brinsop Hall Coal Co., L. R. 20 Eq., 769, 772; Brookline v. Mackintosh, 133 Mass., 215, 224. And it follows from what we have already said that the plaintiff is entitled to an injunction which will restrain the defendant from discharging into the stream any noxious or offensive substances to such an amount or in such a quantity as to affect noticeably or appreciably the purity of the water, when it reaches the plaintiff's premises, so as to render it materially less fit for drinking or for other uses than it was when it entered the defendant's premises. Simpson v. Hoddinott, 1 C. B. N. S., 590; Merrifield v. Lombard, 13 Allen, 16; Richmond Manuf. Co. v. Atlantic De Laine Co., 10 R. I., 106; Holsman v. Boiling Spring Bleaching Co., 14 N. J. Eq., 335. The court can fix no standard of reasonable use which will be more favorable to the defendant or restrict any further the terms of the injunction to be issued. The defendant must at its peril see that it does not overpass this limit.

Nor can an injunction properly be refused [illegible] the ground of the magnitude of the defendant's [illegible] and the importance of its business. Some stress was laid upon this consideration in Pennsylvania Coal Co. v. Sanderson, 113 Penn. St., 126; but the case was decided on other grounds. The same argument was urged pressed to no purpose in the somewhat similar case of Lockwood Co. v. Lawrence, 77 Me., 297; Silver Bleaching Co. v. Wanskuck, 13 R. I., 611; and Holsman v. Boiling Spring Bleaching Co., 14 N. J. Eq., 335. And here, as in the case last cited, the effect of the injunction will not be to stop the defendant's work or to interfere with its manufacturing industry, but simply to restrain it from discharging offensive matter into the stream and thereby polluting the waters which flow through the plaintiff's land. Here, as in that case, it does not appear that the offensive matter cannot readily and at small expense be otherwise disposed of; if a system of filtration or other purification is necessary, the expense of this should not be thrown upon the plaintiff. Richmond Manuf. Co. v. Atlantic De Laine Co., 10 R. I., 106. Nor is it material that other causes have contributed to the pollution of the stream. This does not excuse the defendant for its wrong doing. Crossley v. Lightowler, L. R. 3 Eq., 279. This is the principle of Corey v. Havener, 182 Mass., 250, and Onligham v. Butler, 189 Mass., 288, 293. Nor is this a case in which the defendant is simply discharging noxious matter into an already polluted stream. It is expressly found by the master that the water when it reaches the defendant's premises "is good, clean, clear brook water, fit for any kind of manufacture or for domestic use."

Accordingly we are of opinion that the plaintiff's exceptions to the master's report were rightly sustained, and that the rulings of law made by the single justice upon them were substantially correct.

The defendant's counsel have argued only certain particular questions arising upon their exceptions to the master's report; and it is not necessary to say anything more of the other specific exceptions than that we see no reason why they should be sustained. There is no occasion as to them to add anything to what was said in the memorandum filed by the single justice.

(1) The defendant's contention that the master was not justified in finding that the defendant made an unreasonable use of the waters of the stream does not call for any special discussion. We have already shown that this is not the material question to be considered. But we ought to add that in our opinion the findings of the master were warranted by the evidence, and were as favorable to the defendant as they properly could have been made.

(2) Nor, for the same reasons, can the defendant's contention be sustained that the master should have fixed some standard of a reasonable use, and should have found how far the discharge of waste or other noxious matter by the defendant exceeded in quantity or character such a standard. This matter has been already sufficiently considered.

(3) The finding by the master that the defendant had not acquired any prescriptive right to pollute the waters of the brook was justified. It may be that we could not have set aside a contrary finding; but the question was for the master.

It remains to be determined whether the plaintiff has lost or waived his right to have his damages assessed, or whether the case may now, in the discretion of the court, be sent back to the master for their assessment.

We have no doubt that it would be within the power of the court to deny the plaintiff any further hearing as to damages. Nor have we any doubt that the court has also the power to send the case back to the master for the assessment of damages. Regis v. Jaynes Co., 191 Mass., 245; Asp v. Warren, 108 Mass, 587. It is, at any rate, possible that the plaintiff may be found to be entitled to large damages. If so, he ought not to be deprived of the opportunity to show this by reason of any mistake of his attorneys or of any misapprehension that may have arisen between the master and the attorneys.

Accordingly, a decree should be entered that the exceptions of the defendant should be overruled, and that it be enjoined from emptying or discharging into the brook upon its premises, above the plaintiff's premises, any acids, soaps, compounds of soap, or of iron, chemicals, scourings, dyestuffs, sewage, or any objectionable substances whatever, in quantities that noticeably or apreciably affect the purity of the waters when they reach the plaintiff's premises, or render them materially less fit for drinking, domestic or other uses at that point than they are when they enter the defendant's premises, and that the plaintiff be permitted to move for a recommitment of the case to the master for an assessment of damages if he desires so to do.

So ordered.

A JADE MINE in Siskiyou County, Cal., is said to be the only one of its kind in this country. Jade was discovered there in 1906, and samples were sent to Germany for test; reports thereon showed it to be of standard grade, and susceptible of a high polish.

EFFECT OF STEAM CURING ON THE CRUSHING STRENGTH OF CONCRETE.

There is no certain method known at present whereby concrete may be artificially aged so that it will reach its permanent set in a shorter time than under natural conditions. To get a good hard concrete the surface must be well sprinkled with water at regular short intervals for some weeks after placing and to save this time some manufacturers of concrete blocks have been submitting their products to a steam bath immediately after molding. This method of accelerating the setting of the concrete is, of course, impossible in mass concrete, and its beneficial effect not at all certain in block concrete. In order to investigate the efficiency of the method, Messrs. Rudolph J. Wig and Robert F. Havlik, of Lewis Institute, Chicago, carried on during the past winter a series of experiments the results of which were embodied in a thesis presented to that Institute.

The program as first outlined was quite lengthy. Lack of time, however, reduced the scope of the experiments performed during the past winter, but the experimenters are working at present on an extension of the same problem at the Structural Materials Laboratories of the U. S. Geological Survey at St. Louis. The tests herein described are on concrete columns submitted to a steam bath of either 2½, 10 or 20 lbs. pressure, for periods varying from 3 to 72 hours. The columns were tested to compressive failure at periods of 2, 7, 28 and 84 days. Part of these columns were left to age naturally after the steam bath, part were submerged in water and the rest were sprinkled in air from four to six days, after the steam bath, this subsequent treatment always terminating at the seventh day. For comparison, tests were also made upon similar columns which were submerged in or sprinkled with water, but which were not treated with steam. A third set of tests was made with a certain amount of carbon dioxide gas mixed with the steam, a method used by some manufacturers.

The tests were made on over 400 machine-mixed concrete columns 8 ins. in diameter and 16 ins. high. The concrete was made from a standard cement and good aggregate in a carefully proportioned mixture of 1 cement, 3 sand and 4½ gravel. The columns were molded in sheet iron forms and tamped in place by a pneumatic hammer under 80 lbs. pressure. On account of difficulties in moving and storing in the steam tank while the concrete was green, the columns were kept in the molding-room for 24 hrs., during which period they were kept wet by sprinkling. At the end of this 24 hrs. the columns were submitted to the required treatments.

The steam curing tank is shown in the accompanying figure. It is 3 ft. in diameter and 6 ft. long, with a 10x16-in. manhole in one end. By arranging a shelf about 8 ins. from the bottom of the tanks and another through the center, room was found for 28 columns. To make sure of saturated steam, a 6-in. water level was arranged for in the tank. The steam was fed from a high pressure main through about 12 ft. of uncovered ¾-in. pipe to a Davis pressure regulator, thence to four ½-in. feed pipes which ran about 2 ins. below the water level and terminated at successive points throughout the length of the tank. The steam was fed through the medium of the water in order to keep the water near the boiling point. When the columns were in place in the tank, the steam was fed in slowly in order to gradually heat up the water around the feed pipes. The back pressure valve was held open to permit the escape of the air in the tank, and after about 15 min., the air being exhausted, the back pressure valve was closed and set and the steam regulator fixed for the required pressure. At the expiration of the test the main feed pipe was shut off, the steam was exhausted through the back pressure valve, the manhole cover was removed and the columns were left in the tank for from 12 to 24 hrs., or until they were cool enough to handle. On account of the drop in steam pressure in the plant over night it was nearly impossible to maintain, for any length of time, a pressure higher than 2½ lbs. For that reason the 10 and 20-lb. tests were limited to short periods and were not sufficiently complete to make any reasonable deductions therefrom.

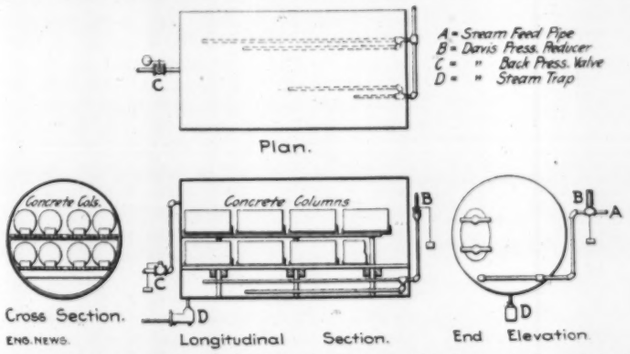


FIG. 1. STEAM BATH IN WHICH CONCRETE COLUMNS WERE TREATED.

After the steam treatment, three sets of treatment were carried on. The columns in the first group were allowed to set naturally in air at a temperature of 50° to 60° F.; those in the second were immersed in water (temp., 60°-67° F.) for a period of six days; those in the third were placed in a moist room (temp. 45°-55° F.) and kept wet for six days with a garden sprinkling can.

Columns which were cured in water and sprinkled in air without steam treatment were left in the molding room 24 hrs., then immersed or sprinkled for six days.

To get an idea of the effect on concrete of carbon dioxide combined with steam, 12 columns were placed in the curing tank and treated with a mixture of the two. The steam was admitted as in the other tests, and when the desired pressure was obtained, 20 lbs. of carbon dioxide was admitted, 5 lbs. at the start and the remainder at 1¼ lbs. per hr. The columns so tested were hand-mixed, but similarly mixed columns were tested for the other cases and no differences were found from the results of the machine-mixed specimens.

The columns were tested to crushing in a 200,000-lbs. Olsen testing machine. They were set on a spherical bearing and bedded in plaster of Paris to insure uniform bearing. The minimum of the two end areas was used to compute the unit crushing values. The accompanying table has been compiled from a long list of tables in the thesis. Each of the values here presented is the average of from two to six separate tests. The curves given are taken from the 2½ lbs. pressure tests and from the tests made without steam bearing.

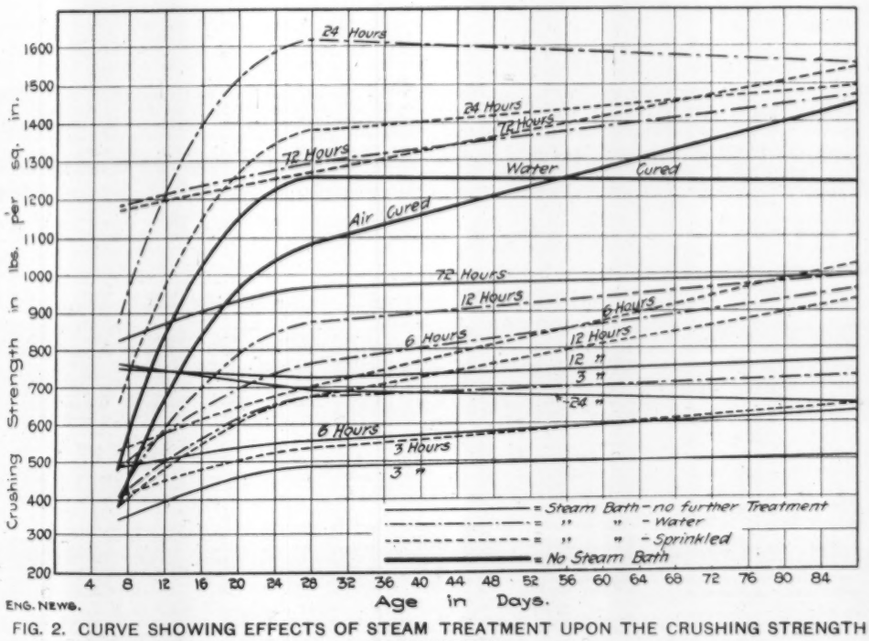


FIG. 2. CURVE SHOWING EFFECTS OF STEAM TREATMENT UPON THE CRUSHING STRENGTH OF CONCRETE.

(Hours marked on each curve indicate time in steam bath.)

TABLE SHOWI G EFFECT OF STEAM CURING ON THE CRUSHING STRENGTH OF CONCRETE.

Age in days when tested	No steam bath N†	No steam bath W†	No steam bath S†	Lbs. of steam pressure.	Under steam pressure — Time in hours under steam pressure — 3 N	3 W	3 S	6 N	6 W	6 S	12 N	12 W	12 S	24 N	24 W	24 S	72 N	72 W	72 S
	Crushing strength lbs. per sq. in.				Crushing strength in pounds per square inch.														
2	....	....	20	2½	*334	....	....	27	....	....	517	....	....	627	....	....	....	....	....
				[2½]	....	....	....	....	....	....	[501]	....	....	....	....	....	....	....	....
				10	338	....	....	....	....	....	....	....	....	....	....	....	....	....	....
				20	....	....	....	....	....	....	618	....	....	....	....	....	....	....	....
7	....	406	425	2½	341	381	408	484	487	531	750	408	385	761	1043	660	824	1181	1167
				[2½]	....	....	....	....	....	....	[548]	[445]	[462]	....	....	....	....	....	....
				10	412	240	236	....	....	....	....	....	....	....	....	....	....	....	....
				20	....	....	....	....	....	....	559	750	613	....	....	....	....	....	....
28	....	1261	1115	2½	486	675	538	558	765	703	726	875	673	692	1619	1382	920	1297	1270
				[2½]	....	....	....	....	....	....	[847]	[892]	[942]	....	....	....	....	....	....
				10	447	830	658	....	....	....	....	....	....	....	....	....	....	....	....
				20	....	....	....	....	....	....	596	853	809	....	....	....	....	....	....
84	....	1250	1426	2½	503	724	641	618	944	1006	763	988	919	659	1557	1488	991	1458	1522
				10	615	877	602	....	....	....	....	....	....	....	....	....	....	....	....
				20	....	....	....	....	....	....	614	977	1084	....	....	....	....	....	....

† { N—Allowed to set naturally in air after steam bath. W—Immersed in water from 4 to 6 days after steam bath. S—Sprinkled in air with water from 5 to 6 days after steam bath.

* 3 days old when tested.

Figures enclosed in brackets are for tests treated with CO_2.

From a study of the table and the curves the following conclusions may be drawn:

(1) Steam-treated concrete receives its primary set sooner than non-treated concrete.

(2) Steam-treated concrete which receives no subsequent treatment has a lesser ultimate strength than concrete allowed to set primarily in air and then subjected to moist treatment.

(3) Concrete treated with steam for a less time than 24 hrs. is not ultimately as strong as concrete not steam-treated, although up to the 7-day tests the steam-treated material shows higher compressive values.

(4) Concrete treated with steam and allowed to set in air with no subsequent moist treatment shows a primary strength above non-steam-treated concrete, but fails to increase on the same curve so that its ultimate values are lower

(5) Steam-treated concrete, subsequently immersed in water, has higher strength values than that subsequently set in air and kept moist by sprinkling. Also the subsequent sprinkled concrete is stronger than concrete not subsequently moistened.

(6) Concrete treated with steam for a period over 24 hours and moistened or wet subsequently has an ultimate strength higher than concrete not treated with steam.

(7) The strength of steam-treated concrete increases with the time under steam pressure.

(8) The experiments on different pressures and with carbon dioxide are too limited to allow of any definite conclusions as to effects.

STATISTICS OF THE RAILWAYS OF THE UNITED STATES FOR 1906.

In view of recent agitation concerning the railways of the country, the railway statistics for the year 1906, as summarized in "Poor's Manual" for 1907, just published, are of particular interest. We therefore reproduce herewith a number of tables from the introduction. The first two tables show by years, from 1899 to 1906, inclusive, and by groups of States, such important items for all of the steam railroads of the United States as mileage, equipment, finances and traffic operations. The table will repay detailed study.

Railroad construction by States during the last four years is shown by Table III. As would be expected, the largest new mileage is in the Southwestern and Northwestern States. The leading facts regarding passenger and freight traffic for the 13 years, 1894 to 1906, are given in Tables IV. and V. Particular interest attaches to Table VI., which shows interest and dividend rates, freight and passenger earnings per unit, gross and net total earnings per mile, and percentages of expenses to earnings, for the past 24 years.

A few figures may be taken from tables not here introduced. The percentage of steel rail mileage has increased steadily, from 37.5% in 1881 to 96.8% in 1906, 75% having been reached in 1889, 90% in 1898, and 94.6% in 1903. The additions to locomotives and to revenue cars of all clases in 1906 were each about double the additions in any previous year, there having been added 5,823 locomotives and 227,424 cars of all descriptions. The increase in cars, it hardly need be said, is almost wholly in freight cars, the passenger, baggage, mail and express car increase comprising only some 5,000 of the total. The total number of revenue cars in 1881 was 667,218, and in 1906, 2,025,858. Passenger cars increased in the same period from 13,947 to 33,896; baggage, mail and express cars from 4,976 to 12,295, and freight cars from 648,295 to 1,979,667.

The net increase in railway mileage for the year 1906 was 5,294 miles, which is the highest figure since 1890, when the net mileage increase was 5,427 miles. The maximum net increase for any one year in the railway history of the United States was 12,876 miles in 1887, and next to this came 11,569 miles in 1882. The railway mileage of the country started with 23 in 1830 and increased by 72 miles the following year. The 20,000-mile mark was not reached until 1856, 100,000 in 1881, and 200,000 in 1902. The number of miles of railway in operation at the close of 1906 was 222,635.

The approximate average cost of railroad and railroad equipment of the country in 1906 is given as $71,388 per mile of railroad in operation as compared with $58,624 in 1880. These costures are approximate, being based on the capital stock, bonded debt, equipment obligations, etc. The capital stock per mile of road was $29,395 in 1880, and $32,533 in 1906; bonded debt, $27,466 and $35,942, respectively.

EQUIPMENT WITH BLOCK SIGNALS has been made compulsory by the Indiana State Railroad Commission for all railroads whose annual earnings are in excess of $7,500 per mile. Systems must be completed by July, 1909. The kind of system to be installed will be determined by conference between officials of various roads and the Commission's signal expert.

THE INADEQUACY OF THE WATER SUPPLY of Montreal for fire protection purposes has been notorious for several years past, and has been emphasized from time to time by the breaking down of pumping engines. A recent accident of this sort has led the Montreal Board of Fire Underwriters (according to a press despatch dated Aug. 24) to invite the Montreal Board of Trade, Chamber of Commerce, Manufacturers' Association, and the banks of the city, to send delegates to confer with the Underwriters regarding measures to be taken to avert the dangers hanging over the city. The Underwriters state that they have exhausted every means in their power in urging the city authorities to increase the pumping equipment and improve the water supply and pressure, also to further safeguard the city by establishing in the congested district a high-pressure and independent water system for fire purposes only; and [that] such representations, accompanied by recommendations made by a competent engineer in the employ of the Underwriters, have met with no satisfactory or adequate action on the part of the City Council, while the public generally evince lack of interest or possibly have failed to appreciate the seriousness of the situation.

TABLE I.—Mileage, Equipment, Liabilities and Assets, Traffic Operations, Earnings, Interest and Dividend Payments, etc., of All the Steam Railroads of the United States, 1899 to 1906, Inclusive.

	1906	1905	1904	1903	1902	1901	1900	1899
Mileage of Railroads	*Miles.* 218,433.46	*Miles.* 214,044.34	*Miles.* 211,074.39	*Miles.* 206,885.99	*Miles.* 199,684.64	*Miles.* 195,886.90	*Miles.* 192,161.93	*Miles.* 187,781.06
2d Track, Sidings, etc.	88,569.48	85,867.45	80,863.03	79,376.03	75,150.75	70,105.45	65,691.29	62,581.72
Total Track	307,002.94	299,911.69	293,937.42	286,262.02	274,835.39	265,992.35	257,853.22	250,362.80
Steel Rails in Track	297,378.15	289,109.18	282,229.35	271,012.70	257,437.11	246,811.60	238,464.13	228,975.54
Iron Rails in Track	9,624.79	10,802.51	11,708.07	15,249.32	17,398.28	19,180.75	19,389.09	21,387.26
Locomotives	*No.* 55,439	*No.* 49,616	*No.* 47,844	*No.* 44,529	*No.* 41,626	*No.* 39,799	*No.* 38,065	*No.* 37,345
Cars—Passenger	33,896	30,777	29,305	28,648	27,384	27,144	26,786	26,184
Bag., Mail, etc.	12,295	10,552	10,417	10,182	9,796	9,609	9,309	9,121
Freight	1,979,667	1,757,105	1,691,427	1,624,150	1,503,949	1,409,472	1,350,258	1,328,084
Total Revenue Cars	2,025,858	1,798,434	1,731,049	1,662,980	1,541,039	1,445,983	1,385,253	1,362,389
Liabilities:	$	$	$	$	$	$	$	$
Capital Stock	7,100,408,976	6,741,056,825	6,447,045,374	6,355,307,335	6,078,990,506	5,978,796,349	5,804,346,250	5,742,151,181
Bonded Debt*	8,467,139,981	7,821,243,106	7,462,091,455	6,792,216,511	6,495,290,839	6,032,469,741	5,756,592,754	5,644,858,027
Unfunded Debt	210,536,466	201,926,773	172,619,537	448,199,448	310,945,867	312,225,536	328,963,335	305,777,858
Current Accounts	722,023,502	630,720,096	516,404,178	648,434,976	479,957,935	456,798,012	422,262,823	377,497,070
Sinking and other Funds	242,256,471	182,853,229	203,962,304	115,201,683	140,679,814	143,670,983	114,800,860	95,013,713
Total Liabilities	16,768,367,396	15,586,252,029	14,802,122,748	14,359,359,953	13,474,565,001	12,926,960,621	12,428,966,022	12,165,327,849
Excess of Assets	686,919,232	650,821,816	620,750,567	572,851,585	479,542,767	381,068,511	339,944,815	291,946,163
Total	17,455,286,628	16,219,573,845	15,422,873,315	14,862,111,544	13,954,107,818	13,308,029,032	12,768,910,837	12,457,274,012
Assets:								
Cost of RR. & Equip.	12,719,736,342	12,143,997,551	11,684,191,134	11,233,311,285	10,868,683,574	10,717,252,155	10,481,493,997	10,254,251,458
Other Investments	3,305,792,328	2,935,278,877	2,712,445,967	2,653,651,625	2,345,515,940	1,976,548,412	1,766,493,086	1,716,507,108
Sundry Assets	488,368,638	331,454,847	408,808,136	552,036,366	455,053,773	390,112,441	338,994,626	325,725,460
Current Accounts	941,389,320	772,844,570	637,328,078	422,312,933	287,854,729	223,616,024	188,994,213	160,789,986
Total Assets	17,455,286,628	16,219,573,845	15,422,873,315	14,862,111,544	13,954,107,818	13,308,029,032	12,768,910,837	12,457,274,012
Miles of RR. Operated	*Miles.* 220,633.33	*Miles.* 215,506.92	*Miles.* 211,835.21	*Miles.* 205,237.12	*Miles.* 197,987.36	*Miles.* 194,974.96	*Miles.* 191,361.98	*Miles.* 186,590.38
Rev. Train Mileage:								
Passenger	488,554,209	467,270,447	446,990,396	431,314,116	408,213,178	391,543,708	373,226,561	355,106,933
Freight	606,324,539	559,434,683	543,447,633	546,380,585	506,210,140	505,466,619	513,667,388	534,391,846
Mixed	27,711,651	26,715,494	28,069,524	22,288,855	22,990,130	20,812,965	20,702,172	20,996,771
Total	1,194,590,399	1,053,420,624	1,018,407,543	999,983,566	934,413,448	917,823,312	907,596,141	910,495,450
Passengers Carried	815,724,118	745,446,641	719,173,6.6	696,949,925	655,130,236	600,485,790	564,695,955	537,977,301
Passenger Mileage	20,943,462,920	20,906,420,668	27,108,454,470	20,898,696,451	19,706,988,781	15,788,669,925	16,313,264,471	14,259,549,365
Tons Freight Moved	1,610,699,829	1,435,321,748	1,295,527,441	1,306,698,858	1,187,198,252	1,064,068,451	1,071,431,919	975,289,941
Freight Mileage	216,885,795,696	187,375,621,53:	172,67,279,384	171,292,198,079	156,622,241,042	148,959,303,497	141,162,108,413	126,991,768,110
Traffic Earn'gs—Pass.	$ 531,231,337	$ 486,490,902	$ 456,942,380	$ 429,705,987	$ 396,513,412	$ 360,702,686	$ 331,402,816	$ 297,556,712
Freight	1,659,925,643	1,478,167,946	1,377,381,306	1,344,150,719	1,197,212,452	1,126,967,652	1,092,835,811	982,436,314
Miscellaneous	165,483,306	147,699,622	144,015,127	135,001,880	127,089,036	125,478,488	117,456,751	118,100,353
Total	2,346,640,286	2,112,197,770	1,977,638,713	1,908,857,826	1,720,814,900	1,612,448,826	1,541,695,378	1,396,086,379
Net Earnings	790,187,712	681,464,468	639,940,087	592,503,513	580,096,277	520,994,727	483,947,526	433,941,689
Other Receipts	100,292,309	80,927,659	81,367,991	89,485,484	77,663,483	68,386,814	67,772,934	55,619,405
Total Avail. Revenue	890,480,021	766,392,147	730,597,918	681,988,996	657,759,760	588,863,541	551,090,460	479,561,094
Payments:								
Taxes	$ 48,140,823	$ 54,353,080	$ 54,325,856					
Interest on Bonds	369,996,366	347,155,897	342,998,750	339,498,707	322,614,909	315,191,178	314,190,502	309,357,309
Other Interest	13,107,169	12,956,346	13,353,529	8,680,451	9,733,560	7,327,334	6,315,026	6,071,451
Dividends on Stock	225,601,945	193,753,989	188,398,008	164,549,147	151,019,537	132,186,335	119,398,879	86,076,368
Miscellaneous	79,806,094	59,856,679	54,357,670	61,326,814	57,408,351	39,935,287	46,153,423	36,549,447
Rentals—Interest	29,613,179	31,716,773	32,307,445	28,675,191	40,632,542	39,127,204	30,948,304	30,221,704
Dividends	27,739,680	22,314,069	23,254,154	26,125,268	27,154,215	24,794,348	21,054,774	20,955,859
Miscellan.	15,043,763	22,938,893	18,190,396	21,320,600	19,970,212	22,586,953	21,200,651	20,040,276
Total Payments	729,005,309	644,516,133	627,977,878	580,113,906	588,523,326	477,355,347	458,460,571	410,882,399
Surplus	151,474,713	121,876,014	92,620,040	101,880,088	109,166,434	111,508,194	92,629,889	68,678,755

* Including, in 1906, 1905 and 1904, real estate mortgages, equipment trust obligations, etc., previously included in item "Unfunded debt."

TABLE II.—Mileage, Equipment, Liabilities and Assets, Traffic Operations, Earnings, Interest and Dividends, Payments., etc., of All the Steam Railroads in the United States in 1906.

	New England Group.	Middle Group.	Central Northern Group.	South Atlantic Group.	Gulf and Mississippi Vy. Group.	South-western Group.	North-western Group.	Pacific Group.
Mileage of Railroads	*Miles.* 8,283.52	*Miles.* 25,730.86	*Miles.* 62,338.96	*Miles.* 27,289.42	*Miles.* 13,523.71	*Miles.* 42,752.19	*Miles.* 96,233.07	*Miles.* 12,552.23
2d Track	1,519.80	7,646.31	5,783.73	738.47	147.94	497.44	560.49	137.05
3d & 4th Tks. Sid. etc.	3,749.85	18,853.90	25,304.32	6,846.41	3,613.36	9,872.90	1,368.23	2,677.56
Total Track	13,553.17	52,217.07	93,364.01	34,884.30	17,284.41	53,061.53	98,196.79	15,156.86
Steel Rails in Track	12,967.76	51,439.92	93,072.01	33,072.61	17,093.66	51,092.97	97,938.62	14,995.11
Iron Rails in Track	510.41	777.65	4,345.91	1,141.29	200.75	1,968.86	258.17	221.75
Locomotives	*No.* 2,773	*No.* 18,947	*No.* 15,094	*No.* 4,812	*No.* 2,210	*No.* 6,653	*No.* 4,092	*No.* 1,536
Cars—Passenger	3,735	12,073	8,420	1,776	1,187	3,372	2,012	1,471
Bag., Mail, etc.	856	4,212	2,999	1,227	436	1,268	778	519
Freight	55,797	708,396	594,654	148,441	90,208	228,004	148,166	39,001
Tot. Revenue Cars	60,388	719,681	606,066	151,454	91,788	207,544	150,951	37,991
Liabilities:	$	$	$	$	$	$	$	$
Capital Stock	323,963,906	1,780,946,608	1,333,771,789	586,023,530	229,809,508	1,073,175,996	802,136,759	724,080,750
Bonded Debt	322,097,411	1,967,104,341	1,994,681,884	718,874,329	322,190,380	1,908,090,790	944,585,074	453,799,964
R. E. Mtgs. Inc. bds. etc.	10,656,267	199,598,879	99,644,051	123,935,573	30,959,572	37,690,972	30,660,183	23,661,263
Accrued Liabilities	5,730,306	24,252,185	17,547,810	9,906,453	4,884,910	14,289,797	5,331,749	4,895,414
Current Accounts	24,178,074	185,994,091	195,641,516	46,478,163	27,414,178	113,959,518	51,772,847	66,622,225
Misc. Liabilities	3,918,562	25,938,635	19,425,865	8,946,312	5,650,436	7,067,777	1,151,784	53,630,571
Sink'g and Other Fds.	13,152,087	66,447,454	72,481,156	13,605,406	6,642,441	8,746,328	48,465,296	12,716,330
Total Liabilities	712,984,617	4,249,502,885	3,863,193,551	1,505,969,900	628,711,417	2,523,684,608	1,944,103,692	1,342,206,746
Excess of Assets	39,008,089	169,117,440	169,501,891	27,578,123	36,827,494	62,561,352	110,826,443	55,961,419
Total	744,886,686	4,418,620,325	4,032,695,442	1,533,548,023	665,538,911	2,586,245,960	2,054,930,135	1,398,168,165
Assets:								
Cost of RR. & Equip.	564,052,284	2,748,109,007	3,997,240,255	1,186,373,978	541,976,754	2,068,991,108	1,373,138,063	942,359,242
Stks. and Bds. Owned	87,754,379	1,018,808,360	256,090,086	150,114,039	88,582,744	158,065,401	452,445,326	299,707,047
R'l Est. & o'r Inv'ts	26,126,094	284,890,260	73,705,726	91,795,951	19,438,265	211,708,418	57,446,905	24,855,045
Sund's & Sink'g Fds.	6,774,605	31,143,825	63,300,399	5,360,217	4,391,988	19,396,285	11,023,388	17,760,176
Materials and Suppl's.	9,923,903	47,969,706	45,017,525	16,561,939	10,873,866	24,933,154	18,973,088	4,422,452
Cash and Cur't Ac'ts.	44,783,844	218,751,416	176,394,110	58,474,367	43,825,782	75,220,787	126,116,406	88,741,436
Other Assets	5,499,567	36,560,851	19,857,391	24,665,079	7,060,092	11,794,822	6,796,899	26,417,435
Total Assets	744,886,686	4,418,620,325	4,032,695,442	1,533,548,023	665,538,911	2,586,245,958	2,054,930,135	1,398,219,240
Miles of RR. Operated	*Miles.* 7,994.89	*Miles.* 27,545.37	*Miles.* 67,186.88	*Miles.* 26,848.85	*Miles.* 11,660.58	*Miles.* 40,582.67	*Miles.* 94,818.90	*Miles.* 13,910.55
Rev. Train Mileage:								
Passenger	34,908,927	198,348,548	148,570,943	42,078,173	18,130,268	59,458,099	26,460,354	21,250,961
Freight	23,729,619	158,458,574	191,588,307	57,945,377	35,969,883	73,252,695	49,705,780	20,470,160
Mixed	1,068,501	4,678,891	5,301,559	4,190,595	2,189,332	3,864,333	3,221,413	3,531,297
Total	59,160,657	296,479,513	345,394,709	104,144,075	56,279,483	136,575,057	69,387,527	45,252,428
Passengers Carried	137,110,030	397,100,096	173,466,737	41,641,535	22,320,008	45,909,181	25,485,672	42,750,804
Passenger Mileage	2,376,008,599	7,622,847,818	5,992,636,774	1,639,196,554	804,989,369	2,058,410,022	2,183,023,945	1,667,000,000
Tons Freight Moved	92,015,049	653,239,886	494,521,988	105,952,219	39,902,998	101,190,510	100,684,518	72,203,415
Freight Mileage	5,253,381,581	70,329,722,492	65,492,117,629	18,426,846,542	9,410,698,114	19,914,306,388	21,071,431,532	6,751,[illegible]
Traffic Earn'gs—Pass.	$ 41,848,197	$ 187,700,737	$ 135,737,440	$ 35,135,744	$ 19,899,506	$ 61,333,949	$ 48,133,947	$ 20,[illegible]
Freight	84,379,458	480,494,597	470,568,910	135,814,536	74,139,388	197,667,276	180,884,869	35,[illegible]
Miscellaneous	10,032,579	80,979,718	52,792,202	14,950,300	8,170,147	30,171,084	13,881,036	2,[illegible]
Total	116,258,234	637,485,052	662,043,678	187,740,877	102,127,948	279,173,859	242,900,479	58,[illegible]
Net Earnings	35,447,758	215,775,008	198,082,804	60,351,506	27,330,139	93,804,841	116,492,584	4,[illegible]
Other Receipts	8,520,827	30,545,913	17,477,502	8,257,580	3,251,981	14,909,556	14,088,659	1,[illegible]
Tot. Available Rev.	35,960,062	252,320,913	215,560,776	65,609,178	30,582,060	108,606,390	130,579,595	4,[illegible]
Payments:								
Taxes	5,174,510	15,082,089	22,193,885	3,584,857	2,496,941	7,435,288	8,106,542	[illegible]
Interest on Bonds	7,460,896	87,585,810	76,888,631	27,199,053	12,985,884	44,894,860	25,209,544	[illegible]
Other Interest	117,885	3,894,594	3,925,707	2,942,317	604,904	1,705,977	246,971	[illegible]
Dividends on Stock	2,627,448	68,401,064	58,388,038	10,734,794	5,749,478	25,689,573	43,815,581	[illegible]
Miscellaneous	2,861,817	22,460,948	18,490,812	4,528,811	2,480,052	11,486,953	13,809,012	[illegible]
Rentals—Interest	3,688,516	21,908,094	5,807,060	1,368,106	1,306,680	2,911,190	4,056,333	[illegible]
Dividends	6,998,556	14,411,970	761,966	1,348,096	118,060	567,500	2,189,000	[illegible]
Miscellan's	94,226	4,394,379	5,943,180	676,296	1,065,364	1,650,327	948,185	[illegible]
Total Payments	36,424,790	292,067,812	250,198,189	56,580,322	26,647,255	94,982,608	100,850,468	[illegible]
Surplus	521,284	50,253,101	25,367,584	13,548,916	3,940,805	13,623,782	29,729,127	[illegible]

GASOLINE LOCOMOTIVES AND MOTOR CARS.

Among the recent applications of the gasoline engine are locomotives for contractors or industrial use, road rollers, and light motor cars for street or small branch railways. Two important features in the locomotive and the road roller are the fuel economy and general convenience due to the avoidance of banking and cleaning fires, or building fresh fires every day. These advantages were outlined in an article on a gasoline road roller in our issue of April 25, 1907. In the present article we describe a new type of locomotive and a light motor car, for particulars of which we are indebted to Fairbanks, Morse & Co., of Chicago.

GASOLINE LOCOMOTIVE.—This machine, shown in Fig. 1, is made in two sizes, the larger having a four-cylinder engine, and the smaller one a two-cylinder engine. The latter machine is 10 ft. 4 ins. long, with a wheelbase of 4 ft., and is mounted on four 18-in. chilled iron wheels. It weighs only 3,600 lbs., but is arranged for the addition of ballast to increase the weight and so increase the tractive power. It is fitted with a two-cylinder four-cycle Sheffield automobile engine, which is practically the same as that used on the Sheffield track inspection cars described in our issue of March 8, 1906. The transmission gear is of a planetary type, which is especially adapted to this class of work, being so arranged that the machine can be run at any speed for any length of time on any gear without danger of racking the engine or wearing out the transmission. This gear is attached directly to the engine, and there is a chain drive to each axle, thus insuring a very steady torque and using the fullest capacity of the engine. The speed regulation is similar to that of an automobile. This machine has speeds 4, 8 and 12 mi. per hr. in either direction. The drawbar pull is 800 lbs., which is rated at ten tons on level track. In other words, the smaller machine is guaranteed to pull ten tons on level track. It is equipped with a water tank and with a gasoline tank of 30 gals. capacity. It may be fitted with a cab and with a housing over the machinery, and will then resemble in general appearance the type of small tank locomotive or "dinky" so generally used on construction works and industrial railways.

GASOLINE MOTOR CAR.—A number of railway motor cars of large size, operated by gasoline engines, have been described and illustrated in our columns, but the accompanying cut represents a very light machine of this class, which is a development of the inspection cars above mentioned, and is intended for light branch line or auxiliary service. After experience with two experimental cars, the one illustrated was built for the Chicago, Rock Island & Pacific Ry., and has been in operation for seven months without requiring any repairs. It runs on a branch line between Searcy and Higginson, Ark., a distance of four miles with a 1¼% grade half a mile long in each direction. It makes 40 miles daily and runs seven days a week. It has carried 330 passengers in one day, and the numbers for April, May and June were 3,874, 4,731 and 5,021,

FIG. 1. GASOLINE LOCOMOTIVE FOR CONTRACTORS AND INDUSTRIAL RAILWAYS.

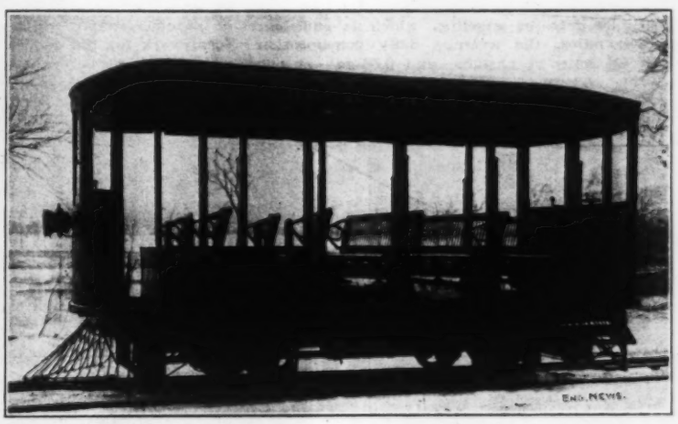


FIG. 2. LIGHT GASOLINE MOTOR CAR FOR BRANCH LINE SERVICE; CHICAGO, ROCK ISLAND & PACIFIC RY.

TABLE III.—Railroad Construction in the United States, by States and Groups of States, during the Years 1903-1906.

States.	1903	1904	1905	1906	States.	1903	1904	1905	1906
	Miles.	*Miles.*	*Miles.*	*Miles.*		*Miles.*	*Miles.*	*Miles.*	*Miles.*
Maine	3.15	25.08	58.93	41.89	Missouri	175.43	418.08	63.37	29.94
New Hampshire	.....	.....	.....	.....	Arkansas	192.61	261.46	213.39	338.71
Vermont	5.35	0.75	5.10	.....	Texas	427.57	317.59	336.61	666.51
Massachusetts	3.86	.....	1.00	4.43	Kansas	11.39	31.17	32.42	46.76
Rhode Island	.....	.....	.....	.....	Colorado	85.99	147.08	87.10	132.72
Connecticut	.....	.....	.....	.....	New Mexico	119.63	0.62	153.71	192.10
New England	12.36	25.83	65.03	46.32	Indian Territory	196.18	260.94	101.00	80.00
					Oklahoma Territory	680.95	279.37	152.77	37.00
New York	46.48	3.00	42.89	95.58	Southwestern	1,891.75	1,715.61	1,140.37	1,432.74
New Jersey	6.27	12.22	11.51	7.56					
Pennsylvania	293.97	205.78	137.90	153.53	Iowa	294 60	26.20	18.43	.....
Delaware	.....	.....	.....	.....	Minnesota	210.22	300.83	131.86	138.83
Maryland	.....	15.75	41.53	2.90	Nebraska	.....	.....	54.01	183.09
District of Columbia	.....	.....	.....	.....	North Dakota	99.97	39.94	522.77	306.32
Middle	346.72	236.75	233.83	259.57	South Dakota	15.56	20.00	113.40	308.86
					Wyoming	.....	5.00	37.00	232.01
Ohio	98.53	120.90	65.64	32.09	Montana	63.00	77.53	1.50	31.65
Michigan	223.99	37.48	85.49	49.23	Northwestern	683.35	469.50	878.97	1,098.78
Indiana	94.72	43.50	300.41	97.37					
Illinois	108.62	221.66	215.09	100.58	Washington	105.39	55.39	48.98	114.43
Wisconsin	36.01	142.95	177.13	163.94	Oregon	16.00	98.00	118.50	55.42
Central Northern	486.87	565.49	744.36	443.21	California	116.54	231.55	77.17	136.71
					Nevada	.....	213.50	94.90	278.87
Virginia	3.91	26.80	47.54	97.09	Idaho	.....	.....	123.33	187.28
West Virginia	36.70	225.60	169.37	111.98	Arizona	118.64	59.66	45.47	32.63
North Carolina	37.85	100.44	110.81	86.62	Utah	76.02	10.00	65.21	114.00
South Carolina	33.48	9.57	43.00	55.00	Pacific	432.59	600.10	573.56	919.34
Georgia	35.27	178.05	256.60	197.09	RECAPITULATION.				
Florida	72.17	119.91	52.14	153.15	New England	12.36	25.83	65.03	46.32
South Atlantic	219.36	660 37	678.46	681.50	Middle	346.72	236.75	233.83	259.57
					Central Northern	486.87	565.49	744.36	443.21
Alabama	77.32	132.17	176.87	94.86	South Atlantic	219.36	660.37	678.46	681.50
Mississippi	49.59	258.04	175.43	125.59	Gulf & Miss. Valley	602.31	728.92	735.64	635.24
Tennessee	76.39	122.34	114.94	52.37	Southwestern	1,891.75	1,715.61	1,140.37	1,432.74
Kentucky	23.55	64.94	93.30	39.74	Northwestern	683.35	469.50	878.97	1,098.78
Louisiana	275.46	141.43	175.30	282.98	Pacific	432.59	600.10	573.56	919.34
Gulf & Miss. Valley	602.31	788.92	735.64	635.94	United States	4,675.23	5,002.57	5,160.22	5,516.70

TABLE IV.—Statistics of Steam Railway Passenger Traffic in the United States for the 13 Years, 1894-1906.*

Years.	Length of RRs. in Operation.	Miles Run by Passenger Trains.	Passenger Traffic.		Passenger Earnings.				Ave. No. of Passengers per Mile of Railroad.	Ave. No. of Passenger Miles per Pass. Train Mile.	Average Distance Traveled by Passenger.
			Pass'ng'rs Carried.	Passenger Movement.	Gross Amount.	Ave. Receipts p. Pass. p. Mile.	Av. Rec. per Pass.	Av. Rec. p. Pass. Train Mile.	Av. Rec. p. Mile of RR.		
	Miles.	*Miles.*	*No.*	*Miles.*	$	*Cents.*	*Cents.*	*Cents.*	$	*No.*	*Miles.*	*Miles.*
1894	176,221	325,981,889	580,993,216	13,600,531,638	375,352,190	2.085	46.34	84.47	1,568	3,253	41.72	23.87
1895	179,154	338,184,598	598,754,359	13,849,082,551	360,999,741	2.069	49.35	79.99	1,458	2,957	38.68	23.88
1896	180,891	337,641,119	595,130,756	13,054,940,943	365,313,256	2.082	49.58	78.58	1,467	2,958	38.66	24.40
1897	180,621	342,464,408	594,106,305	12,494,956,000	358,557,986	2.089	50.30	74.04	1,403	2,791	36.49	24.78
1898	183,216	344,781,149	614,962,888	13,672,497,664	372,580,591	1.904	52.93	79.07	1,488	2,811	39.68	26.55
1899	193,530	358,108,838	637,977,301	14,859,541,905	397,559,712	2.002	55.31	83.79	1,804	2,899	41.64	27.63
1900	190,694	378,236,566	664,980,985	16,313,994,471	431,425,818	2.031	54.67	86.79	1,738	3,066	43.39	27.50
1901	198,823	391,543,708	690,495,790	17,789,689,925	460,702,686	2.028	60.07	92.12	1,861	3,098	45.43	29.63
1902	194,648	403,213,172	655,130,236	19,706,908,785	496,518,412	2.012	60.58	96.34	2,016	3,331	48.87	30.06
1903	208,910	430,378,153	696,906,994	20,895,375,854	528,713,109	2.052	61.53	99.61	2,102	3,418	48.55	29.96
1904	210,352	446,980,208	719,176,676	22,108,494,472	555,063,675	2.058	63.46	101.85	2,163	3,313	49.46	30.74
1905	213,635	467,370,447	745,446,641	25,906,460,668	664,989,076	2.028	65.05	105.77	2,369	3,499	51.16	32.06
1906	218,476	488,554,309	815,774,118	28,642,482,089	819,936,434	2.011	68.73	106.40	2,379	3,734	52.89	31.67

*The mileage from 1897 to 1906 excludes a few hundred miles, each year, of switching railroads, and also the mileage of railroads doing a freight business exclusively.

TABLE V.—Statistics of Steam Railway Freight Traffic in the United States for the 13 Years, 1894-1906.*

Years.	Length of RRs. in Operation.	Miles Run by Freight Trains.	Freight Traffic.		Freight Earnings.					Average No. of Tons per Mile of Road.	Average No. of Freight Miles per Train Mile.	Average Haul per Ton.
			Freight Carried.	Freight Movement.	Gross Amount.	Av. Receipts p. Ton p. Mile.	Ave. Rec. per Ton.	Av. Re. p. Fr't Train Mile.	Av. Rec. per Mile of RR.			
	Miles.	*Miles.*	*Tons.*	*Miles.*	$	*Cents.*	*Cents.*	*Cents.*	$	*Tons.*	*Miles.*	*Miles.*
1894	176,221	475,789,885	674,714,747	82,219,900,498	700,477,409	0.864	103.80	147.23	3,975	3,829	172.61	121.86
1895	179,154	491,410,930	755,799,883	86,567,770,901	743,794,451	0.859	97.38	151.36	4,151	4,263	180.23	115.96
1896	180,891	497,248,256	773,958,716	93,886,853,634	770,424,013	0.821	99.53	154.94	4,259	4,378	188.81	121.32
1897	181,065	500,326,372	788,385,448	97,842,589,150	780,361,936	0.797	98.99	157.77	4,310	4,384	195.56	124.29
1898	184,117	542,824,509	912,973,833	114,586,173,191	995,994,536	0.728	95.18	160.09	4,719	4,956	211.06	125.50
1899	186,324	584,391,846	975,780,941	126,991,703,110	922,436,314	0.726	94.53	172.61	4,953	5,340	227.64	130.04
1900	191,455	513,667,388	1,071,431,919	141,162,108,413	1,052,835,811	0.746	98.30	204.95	5,499	5,596	274.79	131.80
1901	194,453	505,468,879	1,094,096,451	148,920,308,498	1,146,967,852	0.770	103.89	232.82	5,792	5,575	294.70	137.41
1902	197,394	508,210,140	1,192,136,510	156,624,196,084	1,197,212,452	0.764	100.43	235.57	6,065	6,041	306.19	131.38
1903	204,666	545,026,459	1,299,694,091	171,290,310,685	1,337,706,616	0.781	102.93	245.35	6,536	6,350	314.28	131.79
1904	211,232	542,064,037	1,273,077,475	172,613,027,474	1,370,956,494	0.793	107.64	252.78	6,487	6,098	318.42	135.58
1905	214,836	569,434,683	1,435,321,748	187,375,621,537	1,469,518,155	0.784	102.38	262.67	6,840	6,681	334.90	130.45
1906	220,668	608,324,539	1,610,090,822	216,653,795,696	1,650,925,643	0.762	103.08	272.87	7,521	7,295	357.51	134.55

*The mileage from 1897 to 1906 excludes a few hundred miles, each year, of switching railroads, and also the mileage of railroads used for passenger traffic exclusively.

TABLE VI.—Railroad Capitalization and Return for the United States, 1883 to 1906, Inclusive.

	Interest, Average Rate. Per cent.	Dividends, Average Rate. Per cent.	Per Ton per Mile, Average Rate. Cents.	Per Passenger per Mile, Average Rate. Cents.	Earnings per Mile of Railroad in Operation. Gross. $	Net. $	Percentage of Expenses to Earnings.
1883	4.94	2.76	1.294	2.422	7,405	2,879	63.89
1884	4.92	2.50	1.194	2.386	6,663	2,318	65.22
1885	4.97	2.00	1.057	2.199	6,209	2,153	67.17
1886	4.96	2.02	1.042	2.194	6,370	2,376	62.69
1887	4.96	2.17	1.034	2.276	6,799	2,418	64.44
1888	4.48	1.90	0.977	2.248	6,540	2,045	68.73
1889	4.53	1.79	0.970	2.189	6,446	2,086	67.66
1890	4.44	1.82	0.927	2.174	6,875	2,166	68.50
1891	4.41	1.87	0.959	2.184	6,851	2,135	68.83
1892	4.25	1.93	0.941	2.198	6,852	2,068	69.82
1893	4.31	1.88	0.963	2.072	6,963	2,069	70.29
1894	4.19	1.66	0.954	2.035	6,054	1,803	70.23
1895	4.34	1.58	0.930	2.069	6,097	1,804	70.41
1896	4.45	1.52	0.891	2.082	6,293	1,840	70.43
1897	4.34	1.51	0.797	2.069	6,268	1,894	69.74
1898	4.31	1.71	0.758	1.994	6,771	2,111	68.16
1899	4.36	1.92	0.736	2.002	7,161	2,272	68.27
1900	4.37	2.44	0.746	2.031	7,898	2,519	68.10
1901	4.34	2.65	0.756	2.098	8,270	2,628	67.73
1902	4.10	2.97	0.764	2.012	8,606	2,820	67.23
1903	4.17	3.08	0.781	2.052	9,301	2,997	68.04
1904	4.01	3.31	0.793	2.058	9,048	2,909	67.85
1905	3.79	3.37	0.784	2.028	9,643	3,135	67.49
1906	3.99	3.63	0.762	2.011	10,631	3,580	66.33

respectively. The speed is at the rate of 20 to 25 mi. per hr. on level track and the maximum is 28 miles. The fare is 8 cts. The machine is carried on four wheels of Taylor manganese steel, with a wheelbase of 8 ft. 8 ins., and the weight is 7,000 lbs. It can seat 20 passengers. It is equipped with a four-cylinder four-cycle Sheffield engine of the heavy automobile type, but only one of the axles is driven. The transmission is very similar to that of the locomotive above described, and the speed regulation is said to be very satisfactory.

The car can be run in either direction. It carries 30 gals. of gasoline, which is sufficient for 240 miles, the average daily consumption being 5½ gals. of gasoline and 0.66-gal. of engine oil. The car is lighted by acetylene gas. For the weekly run of 280 miles the cost is given as follows: 33 gals. gasoline, $4.62; 4 gals. engine oil, $1; ½-gal. valve oil, 17½ cts.; one charge of storage battery, 25 cts.; 8 lbs. of carbide for lamps, 24 cts.; total, $6.28½. The operator is paid $75 per month. Cars of the same type are in use for street railway service at Salina, Kan., Mineral Wells, Tex., and on the Pacific coast.

THE DEATH RATE OF AUSTRALIA in the year 1906, according to a census bulletin just issued by G. H. Knibbs, Commonwealth Statistician, was only 10.9 per 1000. The death rates of the leading European countries, as given in the bulletin, are as follows, the figures being for the year 1905 unless otherwise indicated: Norway, 14.8; Denmark, 15.0; England and Wales, 15.2; Holland, 15.3; Sweden, 15.6; Scotland, 15.9; Belgium (1904), 16.9; Ireland, 17.1; Switzerland, 17.9; German Empire (1904), 19.6; Prussia, 19.6; France, 19.6.. Italy, 21.7; Austria (1904), 23.7; Spain, 25.9; Hungary, 27.8. These figures are crude death rates; that is, they take no account of distribution of population by ages.

FALL OF A 150-FT. REINFORCED TILE-AND-CONCRETE CHIMNEY AT LA CROSSE WIS.

A high gale blew down a 150-ft. chimney of the C. & J. Michel Brewing Co., at La Crosse, Wis., on the morning of Aug. 11. The chimney was a reinforced-concrete chimney, but of a type which distinguishes it very markedly from others of that class. It was of the Wiederholdt type, described in our issue of July 12, 1906, and shown in its application to this particular structure in the drawing, Fig. 7, herewith. As will be seen, the construction employs burnt-clay tile of peculiar shape, which serves as centering or form-work for the concrete. The space between the inner and outer plates of the tile contains the reinforcing steel and the concrete. This portion of course is like the shell of other reinforced-concrete chimneys, except that it is intersected by the lines of vertical webs.

The chimney was completed at the time it fell, but it was still "green." At its fall it had been finished less than a week, and the oldest concrete in the stack proper was not more than four weeks old.

A high gale blew at the time the chimney fell. According to the Weather Bureau records the wind blew at the rate of 60 mi. per hr. as a maximum, while the chimney was supposed to be "calculated to withstand a wind of 100 mi. per hr." The builders of the chimney, who were also its designers (the Atlas Construction Co., of St. Louis, Mo.), state that the chimney was blown down by a gale of exceptional violence, strictly speaking, a tornado.

We have obtained information concerning this accident from several sources. A short account, written for us by Mr. W. E. Miller, Roadway Inspector of the Wisconsin State Board of Assessment, is given in full below. We follow it with other items of information from several other sources, including the builders, who kindly furnished a statement and the drawing from which Fig. 7 has been prepared.

ACCOUNT OF W. E. MILLER.

A notable failure of an engineering structure occurred at La Crosse, Wis., on Aug. 11, in the destruction by a storm of a large reinforced concrete-and-tile chimney. The chimney was 150 ft. in height, with an inside diameter of 6 ft., wall thickness 9 ins. at the base and 7 ins. at the top. It had been built for the new plant being constructed for the C. & J. Michel Brewing Co., and was finished on Monday evening, Aug. 5, only 5½ days before its destruction. The storm which demolished the chimney and also did considerable damage to other buildings and to the trees of La Crosse, occurred between 8 and 8:30 a. m. of Aug. 11. It is interesting to note here that no one was killed by the storm, and, so far as the writer knows, no one was injured.

The chimney was built of hollow vitrified tile blocks, filled with concrete reinforced by steel bars. It was built on a massive reinforced-concrete foundation, to which it was anchored by embedded steel rods. When the writer examined the ruins, two days after the destruction of the chimney, no one on the ground at the time seemed to know the proportion of cement used in making the concrete; but the concrete itself showed a fairly lean mixture and was quite porous, although all seemed to have been well mixed and of a quite uniform quality. The aggregate was what might be classed by some as "coarse sand," and by others as "fine gravel." Fresh fractures of large fragments of concrete in the

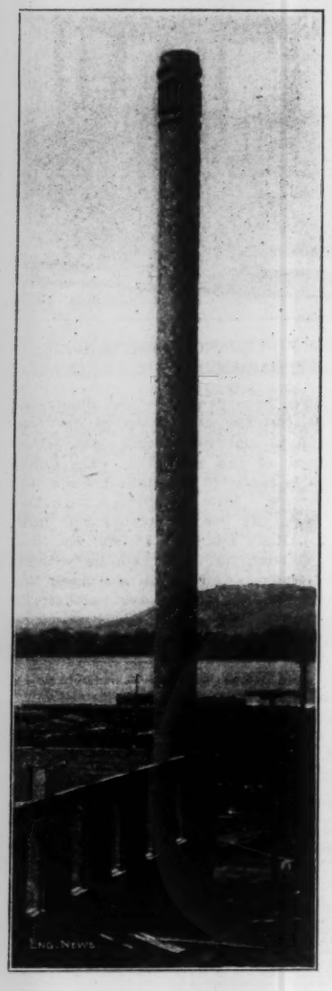


Fig. 1. Before the Collapse.

Fig. 2. After the Collapse, Aug. 11, 1907.

Fig. 3. Looking Along the Line of Fall from the Base.

Fig. 4. Looking Along the Line of Fall Toward the Base.

COLLAPSE OF THE 150-FT. REINFORCED TILE-AND-CONCRETE CHIMNEY OF THE C. & J. MICHEL BREWING CO. AT LA CROSSE, WIS.

ruins showed the concrete to be still "green" (although apparently quite hard), even at the base of the chimney, where it must have been three weeks old. The construction of the chimney had taken about three weeks, so the writer was informed.

The vertical reinforcing of the stack consisted

Fig. 5. A View Close to and Looking Toward the Base of Michel Chimney.

of 1-in. corrugated steel bars, spaced 12 ins. c. to c. [10½ ins. c. to c., according to a drawing sent by the contractor.—Ed.]. The joints of the vertical reinforcement bars were made by simply lapping the bars 18 to 24 ins. in the concrete of the walls. The horizontal reinforcement consisted of rings of ½-in. square bars, corrugated, laid in planes 9 ins. apart throughout the lower half, and 18 ins. apart throughout the upper half of the chimney. There were no ties of vertical to horizontal reinforcing except by the concrete itself.

The anchor rods, which were molded in the foundation, projected up 4 to 5 ft. above the foundation and into the chimney walls. It was at about this distance above foundation that the chimney was broken off by the wind. It seemed to have fallen as one piece, and was shattered after striking the ground.

The form of tile used is shown by the accompanying sketch [not reproduced. See Fig. 7.—Ed.]. The end walls of each tile block were neatly broken out just before laying in the chimney, by aid of grooves made in those ends for the purpose. The central rib of each block is so shaped in the manufacture of the tile as to allow space for the horizontal reinforcing rings [See Fig. 7.—Ed.]. The tile blocks were laid in the walls with vertical joints broken or staggered as in ordinary brickwork, and served both as a formwork for the concrete and as a hard and durable facing material.

The stack stood in the northwest corner of the new building of the brewing company; the (brick) walls of this building had been completed to the second story level. The west wall was laid flat inside the building by the wind, and a part of the north wall was taken out by the chimney, which fell across it. The chimney fell on a line running a little east of northeast from the base of the stack, and across a street adjoining the building. The top of the chimney in falling barely missed striking a frame building occupied by a grocery store on the north side of the street (northwest corner of two streets), but it struck the ground by that building with such force as to cave in the foundation for several feet, making a large hole into the cellar. One of the views herewith shows that the siding was stripped from that frame building on the line of fall of the chimney. The effect of the wind on the store must have been increased on the line of fall of the chimney.

There is a station of the U. S. Weather Bureau at La Crosse, and the charts of that office for August 11 showed a northwest wind with an *indicated* maximum velocity of 60 mi. per hr. for one minute (8:09-8:10 a. m.) and 50 mi. per hr. for about five minutes. The true velocity corresponding to an indicated velocity of 60 mi. per hr. is given as 48 miles and the wind pressure as 9.22 lbs. per sq. ft. Several persons stated that

Fig. 6. Projecting Remnants of the Lower Courses of Michel Chimney.

northwest and southwest winds met in La Crosse during that storm and that the southwest wind was the stronger. There is considerable evidence that such was the case; at any rate, it is quite improbable that a northwest wind would throw the chimney to the northeast. The southwest wind may or may not have been stronger than the northwest wind felt at the weather station. This station is nearly a mile from the chimney and a little east of north of the same.

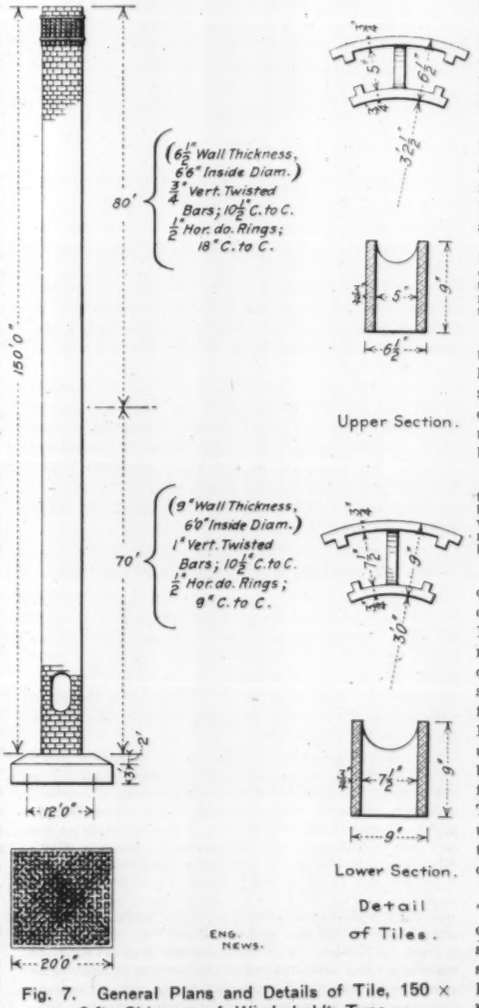

(6½" Wall Thickness, 6'6" Inside Diam.) ¾" Vert. Twisted Bars; 10½" C. to C. ½" Hor. do. Rings; 18" C. to C.
80'
150'0"
Upper Section.
(9" Wall Thickness, 6'0" Inside Diam.) 1" Vert. Twisted Bars; 10½" C. to C. ½" Hor. do. Rings; 9" C. to C.
70'
12'0"
Lower Section.
Detail of Tiles.
ENG. NEWS.
20'0"

Fig. 7. General Plans and Details of Tile, 150 × 6-ft. Chimney of Wiederholdt Type.
Atlas Construction Co., St. Louis, Mo., Designers and Contractors.

The uncertainty of the conditions at the site of the chimney render any calculations as to the strength of the chimney of little value, but the factor of safety obtained even with the strength of the concrete fully developed by age must have been small. It is not certain that the failure occurred by reason of lack of compressive strength of the concrete, as I found some grounds for believing there was a lack of tensile strength on the windward side to resist such a wind as struck it. I found two short pieces of the vertical reinforcing bars still partly embedded in the somewhat fractured chimney walls below the break (on the south side of the chimney) which I was able to pull out and measure. One was 18 ins. long and the other 24 ins. It was quite impossible to make certain whether the side in tension or the side in compression had given away first.

The writer's investigation was made at the special request of Prof. W. D. Pence, of the University of Wisconsin, and it is also due to his desire to have this accident brought to the attention of the engineering profession that this paper is offered for publication.

From the statement of the Atlas Construction Co., who built the chimney, we extract the following:

> While the maximum velocity of the wind recorded by the U. S. Weather Bureau was 60 mi. per hr., this instrument was far removed from the path of the tornado, and the velocity of the wind at the point where chimney was destroyed is almost impossible of estimate. We are in receipt of advice from the U. S. Weather Bureau at La Crosse, that this storm was a tornado. While the chimney was still quite green, it is questionable if it would have withstood this wind even if perfectly matured, as the irresistible characteristics of storms of this kind are well known.
>
> The break occurred about 4 ft. above the foundation, and the quality of the workmanship and material may be judged by the fact that the lower 50 ft. of the chimney (which was the most matured) remained whole and unbroken after crashing to the street.
>
> We can find no fault with any of the material or workmanship in this chimney, and an examination of the concrete after destruction showed entirely satisfactory results, which will be attested by owners of the structure.

The latter statement is weakened, of course, by the absence of any explanation of how the satisfactory character of the concrete was determined. The concrete was specified (by the builders, in a note on their drawing) to be made as follows:

> All concrete filling to be composed of 1 part Portland cement to 3 parts clean sharp river sand, mixed dry until of a uniform color and then moistened until the mixture has the consistency of damp clay. This mixture to be rammed into place until water appears at the top.

The tile were laid up in Portland cement mortar. No information is at hand to show how high the tile were laid up between two successive stages of concreting; that is, how deep the concrete layers were. But the requirement of ramming in the degree specified would limit this to but a few courses of tile.

From another source we have a statement that

> the cement filling was very brittle and could be easily broken with the fingers, and a large number of the vertical bars which had pulled out of their setting were more than 24 ins. long, showing little or no mechanical bond between the bars and setting.

As far as this comment refers to the character of the concrete, it should be remarked that the concrete referred to was probably not more than 14 to 20 days old, the lower part of the stack not having been smashed in its fall. Moreover, concrete which is broken in a fall usually is considerably shattered in its coherence, except when fully hardened, which was not the case here. Further, the condition of the concrete in the upper part of the chimney has no immediate bearing on the collapse, as the stack evidently failed a few feet above the base and fell bodily. The greater velocity and energy of fall of the upper portion would act to produce greater shattering of this portion, even with equal strength of construction.

The matter of adhesion, at the splices, where "bond stress" is specially taxed, seems of more direct bearing. The photograph, Fig. 6, shows somewhat obscurely the undisplaced foot of the stack, with bars sticking out which strike one as having pulled out of the concrete that should have developed their breaking strength. A simple calculation of the bond stress may be of service.

At a wind-pressure of 15 lbs. effective per sq. ft., a common figure for the design of such structures, corresponding to 25 to 30 lbs. on a flat surface, the total pressure is 16,875 lbs., and its

moment at the base 1,266,000 ft.-lbs. Assuming for 10½-in. spacing, that 25 vertical bars were in the chimney, each of 1 sq. in. sectional area, their section moment would be about 42.3 ft.-lns.[3] This gives a tension in the bars of about 30,000 lbs. per sq. in. If the splice is 24 ins. long, the bar would have 96 sq. ins. of adhesion surface. The bond stress developed would be a trifle over 310 lbs. per sq. in. [It should be remembered that Mr. Miller states, after a visit to the ruins, that the bar-spacing was 12 ins. This suggests, but does not prove, that in actual construction the spacing was increased over that shown on the drawing which we reproduce.—Ed.]

Such calculations are, of course, rendered doubtful by the unknown stress condition of the bars. The weight of the stack is carried by the tile, the concrete and the bars in compression, in some sort of distribution. The above calculation assumes that the bars have no initial compression. However, it seems reasonable to conclude that the values computed above are not destructive, with well-aged concrete. The uncertainty of the proper value assignable to bond stress, and the fact that the full attack of wind may occur, as in this case, before the full strength of the concrete has developed, makes it desirable to give considerably longer lap to bars, or, perhaps better, use a mechanical splice to help out the bond stress in the early stages.

MOVING THE OLD MONTAUK THEATER, BROOKLYN.

The projected extension of Flatbush Ave. northwestward from Fulton St., Brooklyn, N. Y., to the Brooklyn terminus of the projected Manhattan Bridge, has necessitated considerable building-demolition in the path of the extension. The old Montauk Theater (now known as the Imperial) stood directly in the line of the extension, in the triangular block bounded by Fulton St. and De Kalb and Hudson avenues. With its 100 ft. lobby to Fulton St., it completely crossed the 120-ft. path of the new avenue. The shape and position of the building are shown in the accompanying sketch-map.

It was decided to move the structure so that it would stand in the new block between the extension and Hudson Ave., with the stage entrance —heretofore on De Kalb Ave.—facing Hudson Ave., and the main entrance on the new section of Flatbush Ave.

The theater is a brick structure, built in 1895. Aside from the roof-trusses, the columns supporting them, and a truss across the proscenium "arch," there is no steel-work in the building. The 45 × 85-ft. rectangular portion formerly fronting on De Kalb Ave., and containing the stage and mechanism, is about 95 ft. high; the remainder of the building is 75 ft. high.

The extension to Fulton St. was torn down. Across the stage-front, beneath the proscenium truss, ten 12 × 12-in. timbers, 38 ft. long, were set up—in pairs—to take the strain from the 4 × 6-ft. brick piers supporting the ends of the truss and distribute it. One or two steel tie-rods were put in, to brace the walls on the obtuse angle at the southeast corner.

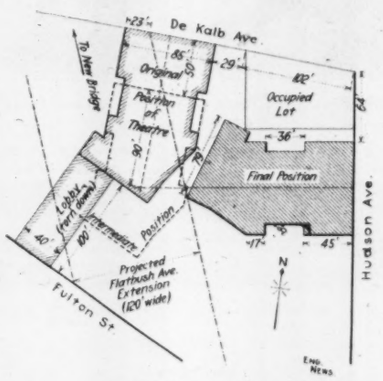
Holes were then cut in the foundation walls, and 15-in. 60-lb. I-beams laid both parallel with and across each other, so as to support the walls. The building was then raised ¼-in. by means of 1,200 jack-screws, the weight of the structure being about 8,500 tons. With the building supported on the jacks, the foundation walls were removed and a cribwork of 12 × 12-in. timbers, supporting 60-lb. steel railway rails, was built underneath. The building then was let down upon 2-in. steel rollers, 2 ft. long—1,400 in all—running on these rails. The rollers were all set parallel to De Kalb Ave., and the building moved directly back 50 ft. therefrom by means of jack-screws. It now stands in that position.

A point 90 ft. from the De Kalb Ave. end, and on the center line of the building, will be taken as a center, and the rollers will be reset radially therefrom. The building will then be turned by means of jack-screws, clockwise, upon this imaginary pivot, until its center line coincides with the center line of its new position. The rollers will then be again reset, parallel with Hudson Ave., and the building moved upon the new center line to its final position.

Between the bottom flanges of the I-beams and the rollers are steel-shod blocks of 12 × 12-in. timber, about 2 ft. in length, so that the rollers do not remain in continuous engagement. They may thus be reset if they get out of alinement as the structure travels.

The arrangement of the I-beams, lining and T-rails is somewhat similar to that shown in Engineering News for Feb. 6, 1896, in connection with the moving of Immanuel Baptist Church, Chicago. While that task involved moving a structure of masonry, and of lifting it 5½ ft., it was not necessary to turn it as in the present case. The ground-level beneath the theater is much lower than the street level, necessitating cribwork of considerable height beneath the rails.

Work was started on June 29, and, as we have noted, the theater now stands 50 ft. back from De Kalb Ave., ready to swing. The new foundation is ready to receive it, and it is planned to have it in commission during the coming theatrical season.



Sketch Showing Moving Route of Old Montauk Theater, Brooklyn.

The work is being done by Iversen, Gustafson & Co.,* under the personal direction of Mr. J. A. Iversen, its President. We are indebted to Mr. Iversen for the data from which this description was written.

It will be of interest to note, in connection with the foregoing allusion to the moving of Immanuel Baptist Church, that the steel rollers on which the theater now stands are the identical rollers that were used on that contract. Mr. Iversen was then Superintendent for H. Sheeler, Contractor, of Chicago, and supervised the moving of the church.

WATER METERS AND METERING IN CHICAGO.

The use of water meters and the payment for water supplied to public departments is a subject of such perennial interest that we give below some quotations from the annual report for 1906 made to the Commissioner of Public Works of Chicago by Mr. Walter A. Shaw, Engineer in Charge of the Bureau of Engineering. Mr. Shaw has recently resigned.

Attention is particularly called to the pitometer work that is carried on, and especially to the portion relating to the parks. The area of all the Chicago parks is approximately 3,210 acres. The pitometer surveys show that the parks consume 1,855,000,000 gals. of water, which at the city rate of 7 cts. per 1,000 gals. would amount to $129,850. For this the Water Department receives no credit. I believe this to be entirely wrong. I believe that the parks, as well as the other city institutions, such as electric light stations, schools, and other public buildings, should pay for all the water they use, the same as any private individual. The water-works system must be maintained and extended out of the revenue it receives by the sale of water. The people of the city of Chicago are taxed for the maintenance of these various institutions, such as parks, etc., and these institutions should be required to account for all expenditures necessary for the maintenance of the same. By reason of these institutions obtaining such a large quantity of water free of cost and without paying any revenue to the water department, the city necessarily must charge more for the water it sells to those consumers who do pay, in order to obtain sufficient revenue for the proper maintenance, operation and extension of the water-works system. Also, if these institutions, especially the parks, were required to show at the end of each year the expenditures account of the amount of water used, I believe they would be more careful and that it would result in a great saving to the water supply. There are certain portions of the city, where beyond a doubt the amount of water being used by the parks materially affects the pressure in that immediate vicinity. I recommend that such action be taken as will cause all parks and other institutions to obtain all their water measured through meters and pay for the same at city rates.

While it is true that the total pumpage of 1906 was 9,500,000,000 gals. greater than in 1905 and the average head 4½ ft. higher, the daily per capita pumping being 204 gals., yet in the seasons of the year when it was warm and dry or when cold weather prevailed many complaints of lack of pressure reached the office. These facts lead me to believe, as I have stated heretofore, that the city of Chicago will never furnish satisfactory pressure for all consumers until all service supply pipes are controlled by meters. This notwithstanding the fact that the water department has now $8,000,000 worth of improvements under way, and that it is contemplated to build in the near future four new pumping stations.

Recently both Philadelphia and New York have engaged experts to investigate water waste in those cities and to make recommendation to legislative bodies for improvements in the water supply. In each instance the authorities have been advised of the large amount of water being wasted, with the recommendation (viewed both as a financial proposition and as to furnishing an adequate service to the patrons) that they should begin the installation of meters at once and proceed with same until virtually all the supply pipes are metered. There are numerous other cities which have actually gone through the experience of supplying water through unmetered service supply pipes and afterwards had all supplies controlled by meter. The result invariably was that the water consumption per capita daily was decreased 50%, thereby enabling them to supply water to their consumers at a satisfactory pressure without any expenditures in adding new pumping stations.

During the year an investigation and report was made showing the number of private corporations using water out of the Chicago water tunnels, conduits and Chicago River, they gaining access to the river by private pipes laid in public streets. The results showed that in many cases these concerns were not paying sufficient revenue for the water they were receiving; also it was developed that there was no uniform rate charged. In most cases the privilege was covered by a special ordinance or order passed by the city council. As a result of these investigations an ordinance was submitted to the water committee, which was afterwards passed by the city council, in which a specified rate would be charged by the city for water used out of tunnels, conduits, river, etc., for the generation of steam, for condensing engines, and for other purposes. This ordinance went into effect Jan. 1, 1907.

The report of the Bureau of Water shows that 2,004 meters were installed, the total number in use on Dec. 31, 1906, being 12,301. During the year 5,913 meters were repaired (about 60% of the number in use up to the end of 1905). The majority of the services to which meters were applied during the year were found to be leaking, and of course it is not known how long these leaks had been a draft upon the water supply. It is pointed out that the most effective, permanent and satisfactory way to stop such waste is by metering the services. Readings were taken from 851 meters for purposes of comparison: 281 meters showed a saving to the consumers as compared with frontage rates, while 570 produced to the city a revenue in excess of the frontage rates. These figures are said to show conclusively the inadequacy and uncertainty of the guess plan by which the frontage rates are levied. The following particulars are given as to tests of meters, those tested being five years old, and the results showing the necessity of testing old meters.

Of the 856 meters referred to, 126 were found to be practically accurate, the remaining 730 show the city to have been losing annually $119,428. In compiling this table, the basis for figuring is taken from the records for five years back. In preparing for this test, all meters (without regard to sizes or makes) were removed, if they had been in service longer than five years. The results of the tests bear out the information shown by the 1905 test. Rotary piston meters and plunger piston meters are proved to be the losers, from the city's revenue standpoint. While but few disc meters were tested, this style of meter shows, as was shown by the 1905 report, that the disc type sustains but a slight loss to the city.

*28 Second Place, Brooklyn, N. Y.

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Little study of the railway statistics reprinted from "Poor's Manual" elsewhere in this issue is required to impress one more strongly than before with the well-known fact that the year 1906 was a truly marvelous one in railway activities. The net gain in railway mileage was higher than it has been since 1890; additions to locomotive and car equipment were each double what they have been in any previous year; the volume of business showed a heavy increase, and while the operating expenses also greatly increased and the average ton and passenger mile rates fell off by a small decimal amount, yet the percentage of dividends to earnings was lower than it has been since 1887, and the average dividend rate was higher than it has been since 1882 (available figures begin with 1883), and nearly double what it was in 1889. The detailed figures, of which we reprint more than usual on account of the great interest in railway and financial matters just at this time, will repay careful study. Had we anything like such comprehensive and reliable summaries for other important industries of the country we could feel positively assured, as all careful observers who have not lost their reasoning powers strongly believe, that there exists a most broad and solid basis for continued business prosperity, all the alarmists and all the timid people to the contrary notwithstanding.

In another part of this issue there is presented a description of the system of electric traction recently placed in commercial operation on a section of the New York, New Haven & Hartford Railroad between Woodlawn Junction, N. Y., and Stamford, Conn. The operation of this, the first alternating-current railway installation designed for a large system and heavy service, will be watched with great interest. From its advocates its operation and extension will receive commendation, while from the advocates of a different system no little criticism may be expected. Already its design and construction have aroused some controversy between the two classes of electric railroad engineers, who seem to have segregated themselves, in an entirely friendly professional way, of course. The divisions referred to, are (1) persons immediately concerned with the direct-current third-rail system, and (2) the advocates of the alternating-current, high tension overhead system. These divisions are typified by the New York Central and General Electric companies, on the one hand, and by the staffs of the New Haven road and the Westinghouse interests, on the other.

Questions have been asked, especially by engineers not engaged in any way with electric railroading, as to which system will be successful in its operation.

To such questions there is but one obvious answer — that both will be successful. The resources of the railroad and manufacturing concern back of each system, the personnel of their staffs and their past achievements assure that. So far as the traveling public will be able to distinguish, it may be safely expected that the trains operated on each system will alike be operated with minimum delay and danger and with maximum comfort. The studies of local traffic conditions on the contrasted roads were made independently, and resulted in the adoption of widely different systems. This indicates that traffic conditions are so different that each electrical system answers its requirements better than could its rival, and better achieves the desired results, which are the same for both: increased capacity, low operating cost per passenger-mile, speed, safety and comfort in transportation.

As the wonderful developments in electrical engineering of late years are largely advancement in alternating-current branches, it does not seem unreasonable to expect that the most striking electrical developments of the future will be in the applications of alternating-current apparatus rather than direct-current. In many lines other than railroading the use of alternating current has increased flexibility, and has made possible extensions and economies which are not possible with direct current. The manufacture of alternating-current apparatus to-day is maintained on a much greater, and an increasingly greater, scale, than that for direct-current, and this industrial development has come about contrary to the opinions and declarations of highly competent engineers that the use of alternating current would inherently be more restricted than direct-current, on account of the intrusion of self-induction, capacity and similar phenomena. If one may judge from the past, this expectation seems justified, and there appears no reason why electric railroading or heavy electric traction, to be still more concrete, should be excepted from the general electrical developments.

For the New Haven installation, 25-cycle apparatus was adopted instead of 15, in spite of a considerable reduction, with the latter, in weight, size and unit cost of motors, in reduced conductor losses and induction troubles, and an increase in power factor of the generator load. This decision was based on industrial possibilities, which became dominant when the entire properties of the New Haven system were considered. Among these properties are the 1,500 miles of direct-current trolley lines and the lighting corporations, demanding a frequency no less than 25 cycles, and whose future usefulness in connection with an extension of the heavy electric traction might have been greatly impaired had the lower frequency on the last-named been adopted.

On account of the network in which those steam lines of the New Haven system, which are proposed for eventual electric equipment, are arranged, a new feature in high-tension power transmission presents itself: the mutual reinforcing of a network of lines. For a given line loss and regulation, the first cost and the cost of power transmission per mile, throughout the area served by the network, are lower than with a simple transmission line. As it has been expressed, the "economic-radius" of the area possible to be served has been increased. The case is exactly similar to the Edison Companies' low tension systems in the larger cities, such as New York, Boston, Chicago. The installation of the New Haven road is far from such completeness as yet, but it is understood that at least preliminary calculations for all the lines have been made. This is believed to be the first case on record where the network reinforcement has entered the calculations of a high-tension power transmission service.

The award of the contract for the main dam of the great Ashokan Reservoir, New York City, to other than the lowest bidder, has naturally aroused a large amount of comment, particularly as the award was made at an estimated total of $12,669,775, as compared with $10,315,350, the lowest bid. While there are many objections to awarding contracts to other than the lowest bidder, yet this journal has always maintained that conditions sometimes make such action advisable. Such seems to have been the case in this instance, judging from the statement issued by the New York Board of Water Supply and given in substance on page 237 of our issue of Aug. 22. It appears from this statement that the lowest bidder had based his estimates for work with which he was familiar on about the same unit prices as had the other bidders and as did the chief and consulting engineers for the work, but that for excavation and embankment, for which immense quantities are involved and on which he had had little or no experience, his figures were so low as to point strongly to heavy losses on the contract. All this the lowest bidder admitted, although he manfully stated his willingness to accept the award and proceed with the work. The Board of Water Supply took the position, in passing over this bid, that experience on all parts of the contract was an essential element to the best execution of the work, and that the possibility of heavy loss by the lowest bidder was very likely to lead to troublesome complications and delays which would be very detrimental to the best interests of the city. While, as we have said, the decision of the board seems fully justified in the light of its statements, yet it should always be remembered that public officials who award a contract at a price in excess of the lowest bid, be it 25% or 1%, are put in a delicate position where troublesome criticism may be expected. This is especially the case where a contract is so large as the one in question, and where the lowest bidder is a contractor of large and successful experience in other lines of work. Many people reason that a contractor who has put in a bid backed by a certified check should be compelled to stand by his bid or lose his deposit. We think this is a mistaken view, inasmuch as the object of advertising for bids is not only to get the work done at the lowest possible figure through competition, but also, and primarily, to secure the prompt and satisfactory execution of the work. The latter can only be done, at least without very great difficulty and risk, through conditions that give reasonable assurance of profit to the contractor. The delicacy of this general question, of course, arises largely through conditions which lead to continual suspicion of favoritism or jobbery on the part of all concerned in contracts for public works. This state of the public mind is very unfortunate, and all the more so because there has been so much to justify it in the past. But when a board composed of highly reputable and able citizens, supported by the best engineering talent of the country, faces such an enormous undertaking as the $160,000,000 water supply project for New York City, it is certainly entitled to the confidence of the public until well-founded reasons for the contrary are established.

They do things differently, if not better, at Philadelphia, where contract awarding has long been reduced to such a fine art that a contract can always be turned in any desired direction and still have it go to the lowest bidder. Such was the case through the long and notorious series of Philadelphia filtration contracts, where high bidders were made low bidders, other means failing, by taking advantage of time-element clauses in the specifications and bids, which clauses were, of course, never enforced, although

officially-declared lowest bidders overran the stipulated time for completing work by months and sometimes by years. The most recent exhibition of contract-awarding as a fine art at Philadelphia took place quite recently, when by choosing the right one of a half-dozen different combinations on two small items in the bids, the favored political contractor secured the contract for completing the preliminary filtration plant at Torresdale by the remarkably small margin of $350 in a bid totaling considerably over $1,000,000. Just how this was brought about was outlined briefly on page 237 of our issue of Aug. 29. Another combination would have saved the city some thousands of dollars, but would have thrown the contract to a rival bidder—who was also a rival in local politics. There may be good technical reasons for this Philadelphia award, but we have not seen any advanced, even by its defenders.

THE GREATEST ENGINEERING DISASTER.

It is with the keenest regret that we record the collapse on Aug. 29 of the great cantilever bridge under construction over the St. Lawrence River at Quebec. We are sure this regret is shared by every engineer who takes the least pride in his profession and its achievements. And the feeling is even deeper than regret. When the newspapers of last Friday morning spread the news of the terrible disaster at Quebec to every corner of the country, thousands of engineers, as they read the story, were grieved and sick at heart. They felt not only horror at the fearful loss of life, sorrow and sympathy for their brothers whose professional and business reputations were dealt a cruel blow when that huge steel structure fell into the St. Lawrence, but also a sense of personal loss as well.

It could not be otherwise. Public confidence in engineers and engineering constructors and in the safety and reliability of their works is an asset of the whole engineering profession. To have this public confidence receive such a blow as this at Quebec is a loss almost incalculable. For decades to come, the Quebec disaster will be quoted, in public and in private, as an unanswerable proof of the unreliability of engineers and their works—of even the best engineers.

For it cannot be said in this case that the disaster was due to the work of incompetent men who posed as engineers. Often it has happened, where an engineering work has failed, that the failure has been traced to the blunders of some quack wearing the professional garb. But at Quebec the work was in charge of men of long experience and the highest professional standing; so much the more, therefore, must the profession bear the responsibility.

There is another fact which makes this disaster a peculiarly heavy blow to the engineering profession. Of all bridge structures in the country which were expected to be built with absolute safety and certainty, we take it, the Quebec Bridge is foremost. We know of no engineering structure anywhere whose failure would have been a greater surprise to the profession than this collapse at Quebec.

Of course, as our readers know, the structure surpassed in magnitude any bridge ever erected; but the problems involved in its design were, after all, simple, and, what is more important, they were accurately determinate.

The work of erection, where ordinarily many chances enter, was in this case subjected to predetermination and calculation as elaborate and painstaking as that required in the design itself. The possibilities of mischance which affect ordinary erection work were eliminated. Each manipulation of every piece had been studied, and the appliances and methods therefor had been prescribed in detail. The magnitude of the weights to be handled compelled this. And the general course of the erection was so laid out that at every stage the structure was fully as safe as the finished bridge. Altogether the erection work at Quebec has been carried on more scientifically, more accurately and more safely than in any other bridge structure ever erected. The collapse of the bridge, notwithstanding this care, overthrows every certainty.

And the surprise of the profession, we take it, is well matched by its mystification as to the probable cause. It often happens, when news comes of an engineering accident, that one well versed as to the general conditions can form some idea as to what must have happened to bring it about. But the early newspaper reports of the Quebec collapse gave no clue whatever on which one could hang a theory of the cause of failure. What could have happened to this towering fabric of steel to send it crashing into the river?

One rapidly canvasses the possible causes of accident to bridges under construction. Traveler failures are a prolific source of disaster to bridges under construction; but the traveler on this hugh structure was as much a matter of anxiously careful construction and handling as the bridge itself. Connections left partially riveted or otherwise unsecured are another prolific source of erection accidents; but in building this great pin-connected cantilever all the main members had to be erected complete as the work progressed; and there was no reason whatever for delaying full wind and sway bracing—as, indeed, it was not delayed. In some types of bridge structure there is chance for doubt as to actual stresses: braced arches, continuous girders, and suspension bridges are examples. But in a simple cantilever there is absolutely no chance for doubt as to stresses. Failures of hoisting apparatus, with fall of main members, have occurred in bridge erection; but they seldom wreck the whole structure and least of all would they be expected to do so on the outer arm of a cantilever bridge, nor at all in a structure of such massive proportions as that at Quebec.

Failing pier foundations wrecked a great bridge over the St. Lawerence at Cornwall, Ont., not many years ago; but at Quebec the piers supporting the huge cantilevers were founded in moderate depth of water and the supporting material was tested with diamond drills to remove the last fraction of doubt as to its reliability at great depth. The piers themselves were of high-class masonry; there was no reason in that region of Laurentian rock for using any but the soundest stone. Even if considerable settlement of a main pier were to occur while the cantilever was under erection, it seems inconceivable that it should set up such stresses in the superstructure as to cause its complete collapse without a moment's warning.

The usual causes of disaster in bridge erection seem, therefore, improbable as causes of the wreck at Quebec. We are led, therefore, to turn to other causes peculiar to the structure itself. The Quebec bridge was to consist of two great cantilevers, with their river arms connected by a suspended span 675 feet long. In erecting this suspended span stresses are, of course, produced in the cantilever greater than those due to the dead load of the span after it is connected. These erection stresses are, of course, accurately computable; but it is natural to wonder whether sufficient provision was made to sustain them. An error was made somewhere, of course, or the bridge would now be standing, and an error at this point may seem less improbable than an error of some other sort.

Again, this bridge exceeded all structures heretofore erected in the size of its main members. It did this, necessarily, because of the length of the span. So far as the eyebars are concerned, equally large bars have been used on some other great bridges, and the heavier stresses in the Quebec bridge were provided for by using a larger number. In compression members, however, all previous sizes were necessarily exceeded. With the disaster at Quebec facing the profession, it is well to confess that our knowledge of the actual limits of safe stress on long steel columns of exceptional size is by no means perfect.

No one can doubt that the designers of this immense structure used the best data at their command in proportioning both tension and compression members to the loads upon them; but in using experience on lesser structures for the design of greater there is always a chance that some element unimportant in the small work will become important in the larger.

It may occur to some critical reader that in this review of the possible causes of failure we are leaving out of account possible defects in workmanship or quality of material. We have done this, however, advisedly. In so huge a structure as the Quebec bridge, a defective eyebar, or plate, or even an ingot of burned steel worked into the material are less of a menace to the structure than would be the case in a structure one-tenth or one-twentieth as large. In a small bridge a single weak eyebar may cause disaster. In the Quebec bridge, where some members are made up of fifty or more eyebars, the weakness of one would be relatively unimportant. Besides this, we risk little in saying that the importance of the structure must have made every one concerned in its building feel the responsibility of securing, not only perfect design and excellent workmanship, but also material of perfect reliability.

And now, following this rapid survey of the possible causes of the Quebec Bridge collapse, made without knowledge of the circumstances attending it or of the condition of the wreck, let us see what clearer light is shed upon the cause by studying these circumstances and examining that terrible pile of scrap on the St. Lawrence shore.

It may seem to the reader that it should be an easy matter to promptly settle, beyond possibility of doubt, what caused the wreck by an examination made on the spot. The first sight of that gigantic heap of torn and twisted steel promptly negatives such an idea. Only the most careful expert analysis can determine the hidden cause of the wreck. Elsewhere in this issue we have endeavored to record the chief superficially available facts regarding the disaster; such as are needed to enable an engineer to form in some degree his own opinion. Here we shall try to set down the deductions which the facts seem to permit. We make no pretense that the analysis is complete. Time has been insufficient and the data have been incomplete.

At the time this is written, at Quebec, on the fourth day after the wreck, *the initial cause of the wreck appears to be the failure of some compression member in the anchor arm of the cantilever.*

It is important to trace the analysis leading to this conclusion, an analysis independent of what we recount, in our descriptive article, about the curiously buckled ninth bottom chord of the west truss.

(1) Neither the main pier nor the anchor pier show the slightest sign of settlement or failure. They are monumental examples of high-class masonry, and, except for a few coping stones displaced or broken by the falling superstructure, both piers are, to all appearance, absolutely uninjured. It is possible that the impact of the superincumbent mass may have loosened the bond of the cement in places, but this cannot yet be determined. But it is certain that the piers still stand in place, with the truss bars on the main pier and the anchorage in the anchor pier still there. The piers did not cause the fall.

(2) *The initial failure was not in a tension member.* This is so important that we deem it well to show the proof in detail as follows:

a. Had a tension member failed first it would have snapped with a loud, sharp report or a series of reports as successive eyebars in a panel parted, which would have impressed every eyewitness. All accounts agree that the very first yielding was silent. The first warning was when the men felt the floor sinking beneath them.

b. Had a tension member failed, especially one of the top-chord members, the structure would have dropped instantly, like a falling body. The failure did not occur in this way. The hazy accounts given by eye-witnesses agree in the one fact that the collapse was rather gradual, at least in its first stages. A time of 10 to 15 seconds is indicated. The time-keeper, who was near the anchor end and had to run uphill to safety, must have occupied at least this much

before he turned around. This man, by the way, does not report jumping a gap at the anchorage, although a gap must have opened there at once if the anchor arm was the seat of the failure. But there are now hanging from the approach span three long strings of track rail, about 75 ft. long, which pulled away from the rest of the track on the bridge; these doubtless carried their ties with them for a time and bridged a gap, if a gap did form. The absence of a gap, therefore, argues neither for nor against compression failure or anchor-arm failure. But the slowness of the fall points to a compression member as the one to give way. The gradual fall could not possibly occur in the case of sudden snapping of an eyebar, or, rather, a panel of eyebars.

c. The eyebars of the upper chords of the anchor arm are intact, unbroken and still joined in a continuous chain, from the bottom of the anchor pier clear across the pile of wreckage, over the top of the main pier until they disappear in the waters of the St. Lawrence. In all that pile of torn and twisted and wrenched steel there is only one single broken eyebar thus far discovered, and that is but one bar out of 26 composing that particular top-chord member. It is true the top anchor chain fell on top of the pile of wreckage, and, naturally, suffered much less than the members at the bottom; yet there are places where eyebars received terrible punishment, were bent, twisted and distorted, and in spite of this, during a whole day's examination by two of the editors of this journal, not one eyebar, with the single exception noted, was found with even a crack across its edge. The importance of this fact to the art of bridge engineering we shall enlarge upon at another time. Its bearing on the question whether a tension or compression member caused the wreck is the point we would emphasize now.

(3) The failure did not occur in a compression member of the river cantilever arm.

If a strut had collapsed somewhere near the end of the river cantilever, the rest of the structure shoreward would have remained standing, or, at least, would have very slowly collapsed progressively and probably not far toward shore. All accounts agree with the appearance of the anchor-arm wreckage in showing that the failure did not occur in this way. There is, indeed, a bare possibility that a failing member on the river side of the main pier and near the pier might have buckled the towering main post over this pier and so caused the wreck of the structure; but everything indicates that this is not a correct record of the failure. As the wreck lies, the members, with the exception of some members of the bottom chord, have all been dragged over toward the river, due, it is believed, to the fall of the river arm as a whole, dragging the top chord and its attached members with it, when the failure in the anchor arm deprived the river arm of support. The main tower posts are bent and broken, it is true; and very badly broken. But this would have been caused both by the collapse of the web members attached to them on the shore side and by the riverward pull of the eyebar chain over their tops. The survivors agree, moreover, in the opinion that failure began in the anchor arm.

(4) The failure was in a main truss member and not in any of the cross bracing.

All the wind and sway bracing was in place and fully connected, and there was no wind of any account when the bridge fell. Further, the trusses fell quite generally in the plane of their original position. The evidence of witnesses, moreover, speaks of no sidewise swinging, but only of the downward motion.

(5) The probabilities are against the failure beginning in a main post above the floor level. The time-keeper, who was facing the probable point of failure, had his first warning by feeling the floor yielding beneath him. A buckling upper post within a hundred feet or so of him would almost certainly have been seen.

(6) No indication as to the probable point of failure is to be seen in the fact that the wreck of the anchor arm on the foreshore lies slightly to the east of its original position. The center of gravity may be 8 to 10 ft., more or less, east of its location when the span was in position on the piers. But when the great height of fall is considered, it is impossible to conclude anything but that the structure, or its anchor arm at least, went down in perfect verticality.

Thus the probability is established, we think, that a compression member in the anchor arm, and that member not a post, but a section of the bottom chord, was the seat of initial failure.

It may be thought that the next step, locating the actual responsible member, would be easy; that one need only go to the site, examine the wreck, and point to the weak link. The facts set forth in our descriptive article as to the buckling tendency noticed in the ninth left bottom-chord section may seem to the reader to put the matter practically on the basis of a certainty. This would be far from warrantable. Not what went before, but what happened at the time, is called for. This must rest wholly on the evidence of the wreckage. The task of constructing herefrom an explanation is not an easy one.

But at present the explanation of greatest probability is the failure of this ninth left-hand bottom chord. This explanation rests on one most weighty fact: Of all the bottom-chord sections of the anchor arm (all of which have been fairly well traced) there is only one that exhibits characteristic buckling distortion, and that is this ninth chord. All the others are bent and crushed, broken at the splices, cracked across, burst open, and most variously battered, but none has a well-defined buckle. The ninth of the left truss, however, is not merely buckled in indisputable manner, but it is doubly bent in a closely folded S-shape, and both its ends still lie practically in their original direction. Did this chord crush as a *result* of the fall. That event happened to all the posts, as our photographic views show strikingly, but not to the chords. The posts had the crushing endwise impact of the fall to withstand, but the chords only fell laterally. A chord member swung forward against the pier masonry might well be buckled. On the left side a tendency in this direction is indeed observable in the eighth chord. But the ninth chord lies far from the pier, in place, as it were, and can hardly be conceived to have returned after striking the stonework; especially is this obvious as chord 10 lies not far out of place as compared with its original position relative to the ninth, being on the pier side of chord 9.

We believe that the most thorough study of all that relates to the present and past state of chord A 9 L must be among the first things to engage the attention of those charged with the investigation of the disaster.

We have already alluded above to the lack of absolute knowledge as to the strength of steel columns of enormous size, such as were of necessity used here. These compression members were designed for a unit stress under full dead, live and wind loads of 24,000 lbs. per sq. in., about two-thirds of the elastic limit of the metal. They were carrying at the time of failure not more than two-thirds of this amount. Were these compression members able to safely carry this stress? Were the plates and angles of which they were built up so thoroughly braced and connected together as to make the whole member act as a unit? Their design was made and approved by the ablest engineers in the profession. No one has dreamed of doubting their strength; but now, with the testimony of that gigantic collapse, every engineer must long to know, by absolute trial, what such huge columns can safely bear.

For, it is not proper to say that the history of several slight injuries to the buckled chord member relieves the weight of doubt in this matter by furnishing the explanation of abnormality. It cannot be said that a member is abnormal which is straight and sound enough to be per se acceptable under careful inspection. Is it at all certain that the undiscoverable variations of manufacture may not produce, in regular process, undisturbed by mishap, a column identical with this one? If inspection can not differentiate it, what surety have we on this point?

No, the doubt lies farther back. We step up from the ordinary columns of ordinary construction, tried out in multiplied practice, to enormous, heavy, thick-plated pillars of steel, and we apply the same rules. Have we the confirmation of experiment as a warranty? Except in the light of theory, these structures are virtually unknown. We know the material that goes into their make-up, but we do not know the composite, the structure.

It is at exactly this point that the Quebec Bridge failure becomes of importance to the whole engineering profession. Until the cause is absolutely determined—if indeed it can ever be—or until the profession has actual results of tests of huge columns at its command, a cloud of doubt rests upon us as to the margin of safety in every great bridge structure; at any rate when the unit stresses are forced up to the point deemed safe by the designers of this bridge.

Long and careful inspection of the wreck shows that the material was of excellent quality; that the workmanship was remarkably good. The end connections of the compression members were remarkably massive and well wrought together. The doubt all centers around the design of those enormous long columns of which the lower chord and the vertical posts were made up. Did one of them fail under a load only one-half the elastic limit of the material in it? That is the question which must, for the present at least, be left unanswered.

ELECTRIC TRACTION ON THE SOUTHERN PACIFIC R. R., Sacramento Division, is to be thoroughly investigated, as a solution of the problem of increasing the capacity of this line over the Sierra Nevada Mts. The entire transcontinental freight and passenger traffic of the Union Pacific system is carried over this division. In a distance of 83 miles there is a difference in elevation of about 7,000 ft. This distance forms a part of the division between Rocklin, Cal., and Sparks, Nev. This mountain division comprises 136 miles of single track, having 31 miles of tunnels and snow-sheds and many sharp curves. The increase of capacity, which will be necessary in the near future, may be realized by a relocation with decreased grades, longer tunnels and a second track. Such a relocation would necessarily be so expensive that the one alternative of electric motive power may become feasible. The latter solution of the problem has been studied for some three years by Mr. Allen H. Babcock, Electrical Engineer of the Southern Pacific. The engineers of the larger electrical manufacturing concerns have already made preliminary studies of the line for the benefit of their companies in preparing for possible developments. Mr. Frank J. Sprague, 20 Broad St., New York City, Past Pres. Am. Inst. E. E., who has been a member of the Electric Traction Commission of the New York Central Co. for four years, has been invited to cooperate with Mr. Babcock for an entirely new study of the possibilities of change in motive power and for the formulation of a report to a Board which will have authority to review the report and make recommendations to Mr. J. Kruttschnitt, Chicago, Ill., Vice-President and Director of Maintenance and Operation. This Board is to be composed of three engineers, from the Southern Pacific staff, in addition to Messrs. Sprague and Babcock. If electric traction is found feasible the board is to recommend a general scheme, attention being given to details of the installation in the broadest way only. If electric power is adopted Mr. Sprague is to continue as Consulting Engineer.

ELECTRIC TRACTION ON THE BITTER ROOT DIVision of the projected line of the Chicago, Milwaukee & St. Paul R. R., in Montana and Idaho, is reported as having been adopted. This line passes from Missoula, Mont., through Lost Pass of the Coeur d'Alene Mts., and follows the St. Joseph River for about 100 miles, west of the divide, and make a junction with the Northern Pacific at Chatcolet, Idaho, on Lake Coeur d'Alene. On 150 miles of this line there are reported to be some 10,000 ft. of tunnels projected, varying from 4,000 ft. in the Lost Pass to 50 ft., where the location cuts through projecting cliffs. The heaviest grades on this mountain division are reported to be 1.7% compensated, with 10° curves. The projected power development will be at various points on the St. Joseph River, along the line of the Chicago, Milwaukee & St. Paul. The Idaho & Montana Power Co., a subsidiary corporation, has filed claims along the river and will handle the development. In addition to furnishing electric power for operating this mountain division, it is expected that current will be transmitted to now remote districts for lumbering and mining, and that branch lines will be built.

THE FALL OF THE QUEBEC CANTILEVER BRIDGE.

The great Quebec Bridge over the St. Lawrence River, half completed, failed suddenly on Thursday afternoon, Aug. 29, 1907, and collapsed into a gigantic scrap-heap. It was 15 mins. before the end of the day's work, and 85 men were on the bridge. Eleven were rescued, more or less seriously injured. Of the 74 dead about 20 bodies have been recovered.

The fall of this bridge ranks with the greatest engineering disasters in history. In our impression, indeed, it is the greatest. The bridge was to be of unprecedented size. The highest acquirements of the bridge-builder's art were called into service for its construction. The most elaborately careful predetermination marked all stages of its erection as well as its design. Before it actually fell every one competent to speak would have said that failure was an engineering impossibility. Now, the 20,000 tons of steel piled along the foreshore and in the river—some of it in 200 ft. of water—bears witness to its possibility.

The facts about the structure and its collapse, as far as determinable in the two or three days available, are briefly as follows:*

DESCRIPTION OF THE BRIDGE.

The Quebec Bridge, crossing the St. Lawrence about 9 miles above Quebec, where the river is nearly half a mile wide and 200 ft. deep in mid-channel, was to have the longest span of any bridge in the world—1,800 ft., exceeding the span of the Firth-of-Forth bridge by 90 ft. Like the latter it is a cantilever bridge. Its total length is 3,240 ft., comprising two approach deck spans of 220 ft. each, and a cantilever structure 2,800 ft. long, made up of two 500-ft. anchor arms, cantilever arms of 562½ ft., and a suspended span of 675 ft. The clearance above high-water was to be 150 ft. for a distance of 1,200 ft. Two railway tracks, two electric car tracks, two roadways, and two footways were provided. The enormous dimensions and great live load made the bridge a huge structure in every sense. The main towers or posts, 315 ft. long between end pin centers, rose to a height of about 400 ft. above high water. The principal members were of phenomenal dimensions. The section of the compression chord, 4½ × 5½ ft., and of the main tower post, 5 × 10 ft., exemplify this. In general the structure was pin-connected, employing rows of 15-in. eyebars for its top-chord chain and all other main tension members; the compression members generally had riveted connections, but the posts were pin-connected to the bottom chords and the latter were pin-connected to the shoes, resting on the 24-in. pin which carried the main post.

It was to form a very important link in the Canadian railway system; several railway lines were to connect with each other and the Grand Trunk Pacific, now building, cross the St. Lawrence over this bridge. Some of the principal dimensions, grouped in tabular form, are as follows:

Approach spans, each	220 ft.
Anchor arms, each	500 ft.
Cantilever span	1,800 ft.
Cantilever arms, each	562½ ft.
Suspended span	675 ft.
Width of bridge center to center of trusses	67 ft.
Depth of cantilever truss at portals	97 ft.
Depth of cantilever truss over main piers	315 ft.
Depth of suspended span at center	130 ft.

*For descriptions of the bridge and previous work executed, see Engineering News, v. 44, p. 189; v. 48, p. 419; v. 49, p. 92; v. 54, p. 272; v. 55, p. 705.

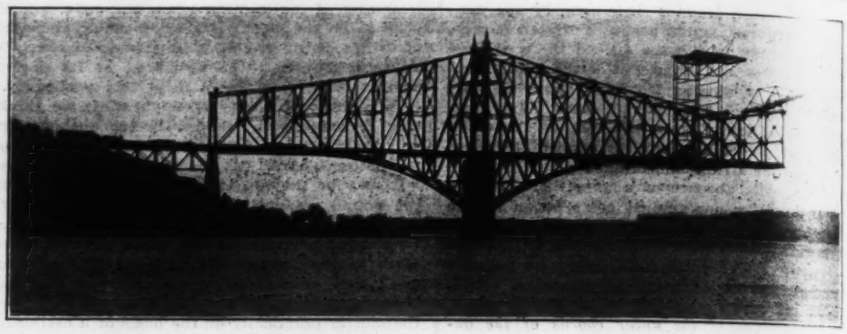

FIG. 2. VIEW OF QUEBEC BRIDGE ON AUG. 14, 1907, FIFTEEN DAYS BEFORE ITS FALL.

The south cantilever is complete and two panels of the suspended span have been erected. The small or top-chord traveler is in position to erect the third panel. The main traveler is on the ninth panel of the cantilever arm, and is being taken down for re-erection on the south side.

Clearance above high water, for width of 1,200 ft.	150 ft.
Total weight of metal work	38,500 tons
Weight of heaviest single piece handled	100 tons
Longest single section shipped	105 ft.
Maximum number of eyebars on one pin	56
Diameter of pins	9 to 24 ins.
Weight of main traveler fully rigged, with its track	1,104 tons

The progress of the erection, in a few words, is thus: The piers having been built under a separate contract, the falsework for the south anchor arm was built in 1905, and in 1906 the entire south cantilever, i. e., the anchor arm and the cantilever arm, was erected. In the present season, 1907, the falsework for the north anchor arm was built. It had been intended to continue on the south side to erect the south half of the suspended span by means of the main traveler, a great outside-running gantry structure, weighing 1,100 tons, and large enough to embrace the highest portion of the 315-ft. tower-bent over the main pier. But the desire of the government to see the bridge completed in 1908, the tercentenary of the founding of Quebec, caused the contractor, the Phoenix Bridge Co., of Phoenixville, Pa. (who had also designed and built the structure and erection equipment), to start dismantling the main traveler so as to move it over to the north side and begin erecting the north cantilever. A smaller traveler, weighing 250 tons, and running on the top chords, was built for erecting the suspended span. This traveler was prosecuting the erection of the suspended span at the time of the accident.

Thus, no part of the north half of the bridge was concerned in the accident, but only the south half, which was nearly complete. The diagram, Fig. 1,* shows the half bridge as it would be when completed. This diagram would represent the south half seen from the east side (called the right-hand side; a member of the east truss is denoted by the suffix "R" in the marking of the truss members; thus ALP3R is the lower section of main post 3 of the anchor arm, right-hand or east truss).

We have represented by another diagram, Fig. 3, the condition of the bridge at the time of its fall. Three sub-panels of the suspended span had been erected complete, lateral bracing included. The fourth panel was just begun, the bottom chord had been swung to place, bolted at its field splice, and at its forward end hung by slings from the overhang of the traveler. The lower eyebar diagonal, shown dotted, was on the bridge ready to be put in place. The separate eyebars composing it were clamped together and in slings for hoisting into position and pinning to the outer end of the bottom chord section.

The view, Fig. 2, taken fifteen days before the collapse, exemplifies the manner of progress, but as our diagram, Fig. 3, shows, another panel had been erected since then.

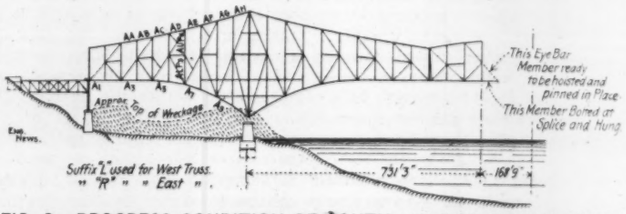
This Eye Bar Member ready to be hoisted and pinned in Place.
This Member Bored at Splice and Hung
Approx. Top of Wreckage
Eng. News.
Suffix "L" used for West Truss.
" "R" " " East " .
731'3"
168'9"

FIG. 3. PROGRESS CONDITION OF SOUTH HALF OF QUEBEC BRIDGE AT THE TIME OF COLLAPSE, AUG. 29, 1907.

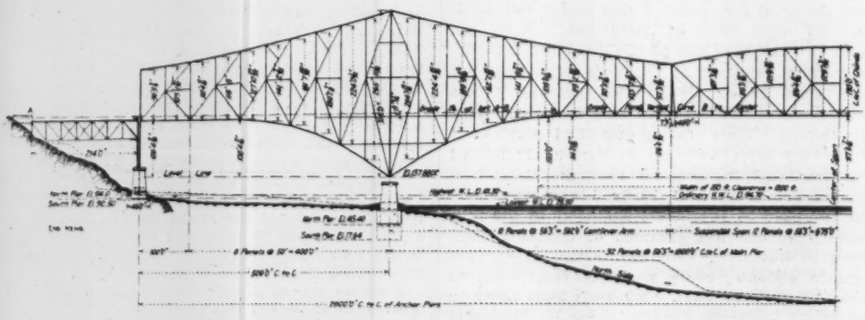

FIG. 1. HALF DIAGRAM OF THE QUEBEC CANTILEVER BRIDGE.

The conditions of loading at the time of the accident are of great importance in connection with the failure. In the first place, the floor system was completed only as far as the floor beams, and temporary placement of stringers for the service track; in a few panels permanent stringers had been placed. The heavy railway and roadway system was not anywhere near its maximum weight. At the extreme end of the extended arm the small 250-ton traveler was at work erecting the suspended span. At the ninth panel of the cantilever arm the large gantry traveler was being dismantled; some 300 tons of its overhang and upper works had been removed, leaving about 800 tons of its weight. We can find no evidence of any great amount of other weight being carried or stored on this extended arm.

There is no question but that the additional load of the erecting machines was greater than the amount of dead load not yet placed in the floor system, or that the erecting stresses in many members exceeded the prescribed dead load stresses. On the other hand, there is small doubt that these erection stresses were much less than the full live and dead load unit stresses called for in the specifications. According to high authority, a unit stress of 20,000 lbs. per sq. in. was specified for a total dead load plus a live load over the entire bridge of the equivalent to a Cooper's Class E-30. It has also been stated by a representative official of the bridge company that for a total dead plus full live load of Cooper's Class E-50 a unit stress of 24,000 lbs. per sq. in. was allowed. As it is hardly conceivable that so large a live load could ever come upon the full length of the bridge, the former figures are probably the more reliable. All compression stresses are taken without column-formula reduction for members in which the

*Reproduced from our issue of Sept. 14, 1905.

FIG. 4. WRECKAGE OF SOUTH ANCHOR ARM, QUEBEC BRIDGE, SEEN FROM THE BLUFF WEST OF THE APPROACH SPAN.

The continuous line of the top-chord eyebars, showing clearly in this view, makes it apparent that no tension failure in the top chord caused the wreck. The lower section of the fourth intermediate post (between panels 7 and 8) of the left truss lies across the wreckage in the distance, with the joint at midheight of the post lying near the right top-chord eyebars.

$\frac{l}{r}$ ratio — is less than 50; this occurs in the main tower posts and in all the bottom chord sections.

A careful analysis of all conditions of erection loading had been made by the bridge company. It was stated to our representative that the stresses in the chords, under the conditions of Aug. 29, were (by recollection) well below 20,000 lbs. per sq. in., probably between 16,000 and 18,000. The actual erection-stress calculations having been made on the basis of using the large traveler for erecting the suspended span, under the changed course of erection, the stresses were lower. The design and calculations throughout were of such detailed character that unless there was some blunder almost criminally bad in the making of this analysis or in carrying out its provisions, there were no stresses existing in the structure which could reasonably have caused failure.

THE COLLAPSE.

The fall of the structure was sudden, at least to the degree that no one on the bridge had time to get off. It was quite unexpected, as is evidenced by the fact that the entire erecting force, including Yenser, the general foreman, and Birks, the Resident Engineer, was out at the work. Practically no eye-witnesses remain whose testimony is of much value in describing the collapse. The men who were rescued after falling with the bridge were out at or near the end of the cantilever, and they are able to say only that the structure sank under them, first slowly and then suddenly. This means, if rigidly scrutinized, only that the outer end did not sway or swing sidewise, as might happen, for example, through a failure in the lateral system. As a matter of fact, there was little wind blowing at the time. Of other eye-witnesses, three may be noted. A man working at the north anchor-arm falsework saw the bridge fall; his story supports the view that the fall was practically vertical. An engine-runner, working a steam locomotive out to the outer end of the cantilever, was thrown into the river, but rescued; he says that he felt the structure sink, and he shut off steam, but the engine continued to run out toward the open end, and soon afterwards bridge and engine were in the river. A third man was on the deck of the anchor-arm, within about 50 ft. of the approach span. He felt the bridge move, and started for his life to shore. He reports that he was running uphill. After crossing the entire approach span to firm ground, he turned to look, just in time to see the bridge go down. Altogether, the testimony adds little to the mere fact that the bridge collapsed.

Most of the bridge, of course, fell into the water. The space between main pier and anchor pier is a sloping foreshore, most of which is dry throughout the ordinary tides, and all of it dry at ebb tide. The tidal rise and fall is some 18 ft. Riverward of the south main pier, the water goes down rather rapidly to 50 ft. depth, then more gradually to a depth of about 200 ft. at mid-channel. Nothing of the wreckage is visible beyond about 100 ft. out from the main pier. Soundings near the middle of the river indicate some 140 ft. of water on the steelwork. The foreshore, however, is piled high with the tangled metalwork from a point about 30 ft. out from the anchor pier to the main pier, and about 100 ft. beyond. All this wreckage lies within lines drawn between the pier noses, with only occasional projections. It slopes up from some 25 ft. height near the anchor pier to the height of the main pier, and passing over this slopes sharply down into the water. About a hundred feet out the ornamental peaked caps over the two main tower posts project a little from the water, with the top-chord eyebar chains leading down to them on the one side, and sharply down into the water on the other side. The shaded area in the diagram elevation, Fig. 3, suggests the lay of the wreckage in approximate fashion.

No description can give an idea of the conditions as well as can the photographs reproduced herewith. We have written sufficient explanation under each view to make it fairly self-explanatory, and can dispense with reviewing them further.

AN OBSERVATION OF THE RUINS.

The most striking feature of the ruins, aside from their close delimitation within the ground plan of the structure, is the continuous lie of the top-chord eyebar chains over the top, up to the last point visible before the dip down into the river. Three panels of both right and left top chord, namely, AF, AG and AH, are on or riverward of the main pier; the tops of the towers also lie in the river. These anchor-arm top chords did not pull the towers back, but were pulled forward by the towers, as the view impresses one. The continuity and little-injured state of these chains is just as striking; this will be referred to further on.

The piers stand massive and intact. Both the main pier and the anchor pier seem almost the same, if looked at from below, as when they were built. Closer examination shows much bad spalling of the coping stones of the main pier; perhaps the coping is more extensively injured under the middle of the width of the wreckage. But there is little doubt that its masonry, as a whole, has not suffered by the mighty blow struck down upon its top. The anchor pier is probably equally intact. There are some hair cracks in the top joints of its coping which may possibly require the upper courses to be relaid or repointed before the pier is quite acceptable again. But a more serious matter is that the upper ends of the anchorage eyebars were bent sharply, edgewise, to about a

FIG. 5. VIEW LOOKING SOUTHWESTERLY TOWARD ANCHOR PIER.

The anchor-towers, still enclosing the unbroken anchorage eyebars, show clearly. The lateral strut between the tops of these towers is broken in the middle, but the diagonals between them are intact.

full right angle by the pulling over of the portal and anchor tower legs. These eyebars are so elongated on their landward edges that they lifted the mortar between them an inch or so out of level. Doubtless, in reconstruction, these lengths of eyebar will have to be renewed. This may make it necessary to take down the upper part of the pier.

The showing of the steelwork as an entirety is of interest only as connected with the question of cause of collapse. This question is discussed in the editorial columns of this issue, in one of its aspects. Here, where only the observed facts are to be set forth, the interest lies mainly in the behavior of the individual elements of the structure. With tacit reference to the photographs shown herewith, particularly Figs. 10 to 20, the following notes are offered. They refer, of course, to the anchor-arm only, as practically nothing of the cantilever arm is above water. But there is no reason to believe that the same observations do not apply equally to all of the structure.

MATERIAL. — Every part of the wreckage speaks of a very good and reliable grade of material. Bending, crushing, buckling, twisting, shearing and tearing are exemplified in the wildest variety of forms, and everywhere the most satisfying pliability and ductility are apparent. To cite a single instance: Where the anchorage legs were pulled over, their riverward lower corners were crushed in over the edge of the pier, as the views well show; these crushed parts of the plates are folded into tight accordeon pleating of much regularity, but we observed no cracks. This, be it observed, with steel which runs rather over 60,000 lbs., we believe, than under.

Some instances of square, sudden breaks in built members give a first impression of hard or brittle metal. This is an erroneous impression. For in almost every such case the same member exhibits, quite near the sharp break, other injuries—shear or tear or folding distortions—that demonstrate a fine degree of workability. In a particular case which struck our notice, a chord section on the left side, there is a sharp, almost concholdal, break through all four ribs of the chord. But while one broken segment remained thus, the other was folded almost double on the longitudinal center line of the rib, the fold being transverse to the sharp fracture; and there is no cracking at the apex of this fold, even close at the broken edge.

The character of the rivets seems equally satisfactory. Large numbers of rivets failed, most of them by shearing, but some few in tension. In the sheared rivets, where indeed a tension may have been coexistent (tending to split the head off), the fractured face always shows a well-marked crescent of pure shearing or cutting action, whose widest part has a breadth of perhaps one-fifth the rivet diameter; the rest of the face being silky or finely granular—the sudden failure after the cutting shear had progressed far enough. Rivets failed in tension in very much fewer instances. But wherever they did it could be seen that quite a number of them had drawn down or necked quite visibly. In one case, a floorbeam was forced down off its connection with the post, a face connection; the upper part of this connection had failed in tension, part by tearing out the post, part by tearing the rivets. The latter were all necked down, and one of them in particular showed as complete necking and as pretty a cup fracture as we have ever seen. And this was a field connection—the rivets were field rivets! In other cases, a riveted connection which failed in tension showed simultaneous failure of rivets and plate, the holes in the plate being bulged through and greatly stretched, and the rivet head being compressed and molded to such a size that it drew through the hole. An entire row of rivets failed in this way.

The workmanship found as good testimony in the wreck as did the material. This, however, is so essentially involved in a structure of this magnitude, if only for facility of erection, that it need not be remarked on in detail.

Before referring to the behavior of different constructional elements, we must make mention of the general character of the details. Briefly described, they were of the highest type, admirable from every point of view in the bridge engineer's field. Central connections were used throughout, at whatever cost of material or difficulty of design. The top chord was, of course, pin-connected throughout, as were also the eyebar diagonals. The posts had the substruts and all stiff members riveted to them, but the post, with its attached members, always connected by pin to the bottom chord; the connection plates of post and substrut, at multiple connections, were extended to form pin-plates, being properly reinforced for this service. Great use was made of the method of multiple pins in a single joint, to give convenient attachment to several sets of eyebars. At the crossing of a tension diagonal

FIG. 7. VIEW LOOKING NORTHWESTERLY TOWARD MAIN PIER.

Sections of both top-chord eyebar chains can be seen. Main posts 3 and 4 of the right truss are crushed down to their bases, and intermediate post 3 is broken and buckled. Part of the main tower post of the right truss leans against the pier and projects above it; it is crushed and torn quite apart over the pier. Its ornamental cap shows slightly above the water to the right.

FIG. 8. ANOTHER VIEW TOWARD MAIN PIER.

Break of main tower post across pier shows more clearly, and the lower tide shows more of the tower cap than Fig. 7. Post 4 of right truss, crushed down, appears in foreground. Sections of the top-chord eyebars and tension diagonals are in view.

FIG. 6. ANOTHER VIEW LOOKING SOUTHWEST TOWARD THE ANCHOR PIER.

Note approach span, overturned anchor towers, first section of lower chord of right truss, first main diagonal with middle portion of first intermediate post attached, section of floor with end floor-beam and stringers, buckled sections of last two panels of upper chord struts (wind truss only), and one post of main portal over anchor pier.

FIG. 9. VIEW OF LEFT ANCHOR TRUSS, LOOKING NORTHEASTERLY TOWARD MAIN PIER.

A bottom-chord section broken and vertically displaced at the pin (shop splice) and broken at the field splice. Broken and buckled diagonal substrut; broken posts; top chord.

with a post, for example, the lower and upper parts of the diagonal had separate pins in the post plates, these latter, in fact, extending out clear of the post for this purpose and forming links between the two sets of eyebars. In packing of eyebars, in grouping of rivets, in detailing of connection angles and plates, in every detail, in fact, thorough excellence was exhibited. By a particular feature of the riveted connections, the curving or concaving of the edges of gussets, the builders, of their own choice, aimed beyond mere strength excellence at an effect of pleasing appearance. Throughout the work, in design as well as in the theoretical and practical phases of construction, the details were, so far as we know them, of a studied excellence, well suited to the exceptional character of the bridge —in large part, indeed, necessitated by the very magnitude of the structure.

EYEBARS AND PINS.—As already noted, the eyebars behaved admirably, perhaps surprisingly so. The top-chord eyebars fell on top of the wreckage, of course, but their impact was still very severe. The diagonals in the panels were more roughly treated, yet they, like the chord bars, show up unbroken and uncracked. Many of the bars were bent, often in short kinks, yet the worst that resulted was flaking off of the paint and scale. In some cases bars were twisted sharply around their own axis, and once or twice a reverse twist adjacent was observed; that is, a short portion of a bar was twisted half-way around, leaving the adjoining parts in normal position. More noteworthy even than the resistance of the bars was the resistance of the heads, which, because of the forging required to form them, are usually considered the least reliable part of the bar. No head was grossly injured. Nor, so far as we know, was any head injured, but it may well be that if removed from their pins some of the bars would exhibit deformed pin-holes and the like. One eyebar only was seen that had a vital injury; this was broken clean and square across, not at the head, but some 4 ft. away. It was an inner bar in a panel, the fourth from one side in a group of 26. The pin nearest the break is bent, its end caps have been burst off, and four eyebars on each side fanned far out and much bent; a considerable force must have been active here, a powerful impact blow, which possibly struck the bar that is broken.

FIGS. 10-12. THREE VIEWS LOOKING WEST A SHORT DISTANCE SOUTHEAST OF MAIN PIER.

Main tower post of right (east) truss. Base section (C P 6 R) with pedestal and stub ends of adjoining bottom chords still attached to main (24-in.) pin. The section just above the base is crumpled and buckled downward to right of base. It continues upward in an uninjured section (C P 5 R), leaning against the pier but buckled and broken off above the coping (see Fig. 8). The stub-end chord section A 11 is the foot of the cantilever arm bottom chord.

The pins seem to have behaved fully as well as the bars, perhaps even better. Wherever bars have been forced off pins, or pins have been forced out of chord-members, the pin surface is in very good condition, generally without superficially apparent injury of any kind. Yet in the vertical fall of chords and posts the bottom-chord pins must in most cases have been subjected to a very strong hammer blow. The pins of course are harder than the bars, and this explains why in some cases the eye of a bar shows rounding or crushing of the edge of the eye without corresponding damage of the pin. The pins were hollow, it may be noted, and a small rod passed through the hollow held on the two end caps.

SPLICES AND RIVETED JOINTS.—The effect of the fall on the splices of members was usually very destructive. Practically every chord splice was broken, at least every field splice. These splices, of course, were not equivalent to the body of the member, as the compression was transmitted through butting contact of the faces. They broke in many cases clean through the splice plate, either on the line of the splice or through a row of rivets. In other cases the rivets were sheared, and the splice-plates merely bent and twisted. The chord-splices, when they broke, parted usually in an irregular line through the pin-hole, where the section was weakened.

Splices in transverse struts, floorbeams and the like, showed similar weakness. They always represented an evident point of weakness in the member against such forces as were brought to bear on it in the collapse of this bridge.

The riveted connections, other than splices, on the other hand, behaved excellently. In most of the photographs herewith which show a compression member there may be seen an almost complete preservation of the part containing the riveted connections, while the rest of the member is more or less completely destroyed. The posts show this markedly. Their lower ends, comprising the pin-plates, connection gussets and cover or batten plates, seem like new, while the remainder of every post is crushed, buckled, broken or torn out of all semblance to itself. This, of course, is an effect of lateral rigidity at the joint. But a distinct effect appears in a

FIG. 13. BASE OF LEFT MAIN TOWER POST; VIEW LOOKING NORTHEAST TOWARD MAIN PIER.

The river end of bottom-chord section A 8 L is in the right foreground.

number of cases, where a diagonal strut, for example, is broken off just outside its connection and uninjured within the connection (e. g., Fig. 17). The effect of the splices is beautifully shown in several of the posts which are bent in multiple bends, crushed flat and twisted, if not broken off, but which yet have the parts containing their three connections, end and middle, solid and undeformed.

This matter of the good showing of the compression members, however, is really only a phase of the subject of the resistance displayed by the compression members generally.

COMPRESSION MEMBERS.—These appear to a most decided disadvantage in the wreckage. Very generally they make a picture of utter destruction. The photographs testify speakingly as to the effects wrought upon the posts, and in

Fig. 14.

each face, and that too with transverse struts at each lattice point, as against single latticing in posts and laterals. The lattice members all were heavy angles, but they failed on these enormous members much as lattice bars do on smaller compression sections.

The unsatisfactory behavior of the compression members is reinforced by the case of the main tower posts. These, like the bottom chords, consisted in their main portions of four ribs, double-latticed together; in these towers each rib was a 5-ft. built I-girder, as against a built channel in the chords. The same failure of the latticing as in the chords appears here. The east tower post, with its four or more separate points of absolute failure, presents a striking picture of this.

Somewhat analogous to the weakness of the latticing is the weakness of the stitch-riveting holding together the individual plates in a heavy compression with multiple webs. This failure does not appear in many cases, it is true, but where it appears the entire series of stitch rivets for quite a length is sheared off. The rivets were unable to hold the several superimposed plates to their duty.

Of course the normal duty of a compression member is not that of being bent and twisted. It may not seem fair, therefore, to argue that the showing of this wreck indicates a lack of strength in the latticing and stitch-riveting. A member is not designed to be thrown about and pounded to the smashing-point. With this in mind, we confine ourselves here to stating the fact that the dominant characteristic of the wreck, as regards structural elements, is the destruction of the compression members.

Before turning to a special peculiar feature of the Quebec bridge wreck, we must refer to the status of the field-riveting at the time of the collapse. In erecting a bridge, of course, the field-riveting lags far behind the erection. Splices are made with bolts and drift-pins; properly only bolts, but practically to some part with drift-pins among the bolts. The riveting gangs following behind the erection work replace the bolts with rivets. In the case of this bridge, where all riveted joints were compression joints, there was less urgency in the riveting than in structures of other type of details. The rule

formed us that, in the anchor arm, out of about 100,000 field-rivets total, only some [illegible] remained to be driven. These, it appears, were mostly in the chord splices from panel [illegible] to the main pier. Riveting was in progress in this portion at the time. Riveting gangs were between panel-point 6 and panel-point 9, we believe, were caught in the fall. In the cantilever arm some 40,000 rivets, out of about 100,000, had been driven. We surmise that practically none of the chord field-splices had been riveted.

It cannot fail to occur to many a one that the presence of bolts in place of rivets in this or that joint or in a number of joints in the chords may have caused the failure. Evidence on this is to be looked for in the condition of the splices, as found in the wreckage. Our examination of the ruins showed practically no case where the injury to a compression chord at the field splice was greater than, or as great as, the injury to other parts of the member. The chord section which is most seriously deformed, in fact, has both its field-splice ends fairly intact as regards the individual ribs, and at that end of this member where the joint was clearly in progress of riveting, the splice is in large part still in place. These facts, it would seem, bear strongly on the question of the causative possibilities of the bolted splices in this bridge, and tend to show that the initial trouble was elsewhere. More generally, perhaps, they show that the temporary bolted condition of compression splices near the joints need not be a matter of much apprehension.

A BUCKLED CHORD.—There is a curious thing about one of the bottom-chord sections of the anchor arm. We have already suggested the general condition of these chords; they are badly deformed and broken, but none of them is buckled. The one exception is Chord A9L, the second section landward from the main pier in the west truss. This chord-section was located in the pile with considerable difficulty. It lies almost under its place in the truss, but considerably inward, east of the general line of the left-hand chords. Its former north and south ends still point roughly north and south. The intermediate portion, however, is buckled into a sharply bent S-shape. Fig. 21 is a sketch made by one of our representatives at the site. It

Fig. 15.

FIGS. 14-15. TWO PARTLY-RIVETED FIELD SPLICES OF THE RIGHT BOTTOM CHORD.

Fig. 14. A nearer view of the lower left-hand corner of the field of Fig. 10.
Fig. 15. The buckled and crumpled post in the background is post A L P 3 R.

FIG. 16. LOOKING WEST AND DOWN AT ABOUT 30° UPON WRECKAGE OF WEST (LEFT) TRUSS.

The lateral strut between two main posts is at the left; the main post extends from the left upward to the right, in the background, and the sway-bracing diagonal lattice strut extends to the right. Much debris of timber staging, an electric hoisting engine, riveting tools and unused rivets were found under this portion of the wreckage.

slightly less degree also upon lateral and other struts. Buckling and twisting or crumpling, usually causing or caused by the complete failure of the latticing, characterize these. The superior showing of the riveted connections appears to be partly due to the plating substituted for the latticing at these points, though in part the thoroughly-designed strength of the connection is itself responsible for the resistance here displayed.

The compression chord shows but little better than the other compression members. Few of the chord sections do not have the larger part of their latticing torn out or crushed out or crippled. These chords were double latticed on

prevailing on the Quebec bridge was that the field-bolting should be sufficient to fill at least 50 per cent. of the holes in a splice. Actually this was carried out by filling all holes in the important splices (if not in all; we are not informed with certainty on this point). As the splices in question all are situated near to the ends of the respective members, they are required to have little more effect than a pin; that is, the stiffness given by the riveting is not urgently required.

At the time of the failure, the field-riveting had progressed nearly to completion on the anchor arm, and not quite half on the cantilever arm. An official of the Phoenix Bridge Co. in-

shows—very roughly and approximately—how the member might be seen in plan and elevation if all the steelwork overlying it and in front of it were removed. The middle of the length of the chord-section is on the middle leg of the S, possibly somewhat nearer the second or lower bend than the upper. In this portion, as the sketch indicates, the westerly one of the four ribs which make up the chord is folded sharply upward and broken off. The middle is not far from this point.

This chord is an intensely interesting object, because it differs from all the others, as described, and because one can not readily find an explanation for the shape assumed. If this

chord dropped with the others, what special forces acted on it to bend it thus doubly? No bending encounter with other parts of the debris would seem to be sufficient to account for the distortion. The two photographs Fig. 19 and Fig. 20 give a more lifelike representation of the present condition of the chord than the sketch. Fig. 19 shows the first or outer bend, looking eastward, while Fig. 20 is a view looking north into the interior of the second bend. Together with the sketch they will probably suffice to make the position clear. We should add, perhaps, that the north end of chord A9L, where it was field-spliced to A10L, lies about over the matching end of the latter. The south end of A9, however, is far from its mate, the north end of A8, which

FIG. 17. POST A L P 3 L, BETWEEN BOTTOM CHORDS A 6 AND A 7 OF LEFT TRUSS.

The shop splice of the chord at the pin is broken, and the field splice 10 ft. to the left is also broken. The diagonal sub-strut coming to this panel-point is broken close to the joint. The post itself is buckled just above the margin of the photograph, its downward returning portion being visible. A C and A D are sections of the top-chord eyebar chain (see Fig. 3). At the left, intermediate post A U T 0000 L is buckled, as is also the diagonal substrut A S P 4 L. The badly buckled chord A 9 L is just behind these posts.

FIG. 18. A NEARER VIEW AT THE POINT WHERE BOTTOM-CHORD SECTION A 9 L LIES.

This chord section lies behind the two buckled posts in the middle foreground, but cannot be seen.

latter is close to the main pier, as appears in the view Fig. 13.

There is no similar condition of affairs in the east truss. Chords A8R, A9R and A10R lie almost side by side forward near the main pier, and while all of them are badly damaged they show no buckling like A9L.

The fact that no explanation of how the shape of this member could have been produced as a result of the fall seems available, leaves as the only remaining theory of the distortion a *buckling of the member under great compressive stress.* If the member, while in place in the bridge, buckled under its load, springing out laterally, it would allow the panel-points at its ends to come together. This would drop the cantilever arm, since the anchor arm would move forward, following up the giving of the chord. The compressive force acting on A9L would thus continue to act, tending to crush the halves of the buckled member together, or break it at the middle, or, if the latticing gave way in the middle part so as to decrease the rigidity here, the member might be curled back upon itself in substantially the shape actually assumed.

It would not be easy to explain why a compression member so far removed from the practical limiting slenderness as is this one should fail under a stress that cannot have been greater than about half the elastic limit. The full dead-load stress in this chord, we understand, was just short of 15,000 lbs. per sq. in. Under the load conditions at the time of the accident, the stress due to the weight of the two travelers probably exceeded by a considerable amount the deficiency in stress due to the absence of much of the permanent floor construction and three panels of the suspended span. But it is not likely that it reached the amount computed for dead plus live load stress. In fact, the stress in A9L due to the two travelers alone is not far from equal to the stress computed for the live-load, about 5,000 lbs. per sq. in. The effect due to the dead load is not easy to estimate even as a mere guess; the reduction chargeable to the dead weight not yet on the bridge and to the absence of three panels of the suspended span, and the increase due to the cantilever condition of the suspended span as compared with its condition when fully erected, may perhaps fairly be taken as reducing the full dead-load stress from 15,000 to say 12,500, a sixth less. This would give a stress in the member at the time of the accident as something between 17,000 and 18,000 lbs. per sq. in. We have already quoted a statement on the part of the Phoenix Bridge Co. that the stresses in the chords of the anchor arm were probably in the neighborhood of 16,000 lbs. per sq. in. on Aug. 29. The engineers of the bridge considered a temporary stress of 24,000 lbs. per sq. in. to be not unsafe, using a column-formula reduction for compression members of length greater than 50 times the radius of gyration. These chords required no such reduction. The stress therefore was perhaps three-fourths of the limiting safe stress; yet on the theory suggested, the member buckled under this load.

PRIOR DEFLECTION OF THIS CHORD.—A very considerable support is given to the theory, however, by another circumstance, namely that as early as three days before the collapse, the member in question was actually observed to be out of line. This observation was made on Monday, Aug. 26. A visible bend in chord A9L was seen on that afternoon, an inward bend. The following day it was measured, with the showing that all four ribs were deflected, at both top and bottom flanges, the amount of the deflection being from about 1½ to about 2 ins. for the several ribs. Fig. 22, a diagrammatic elevation and plan of A9L, to scale, but with the deflection exaggerated (dotted lines), pictures the conditions. At the same time there were indications that the latticing of the chord was stressed differently from its normal state. A rivet in one of the cross struts of the latticing that had been tight before was found loose, and the lattice diagonals "sounded high," as one man put it.

The deflection was not known to increase during the following three days, so far as our information goes. There can be no doubt, however, that its continuance in the deflected condition was a menace to the bridge. The matter was reported to the Consulting Engineer by his inspector, Mr. McClure, who went to New York for the purpose, reporting there Thursday morning, Aug. 29. At the same time the Superintendent of Construction, Mr. A. B. Milliken, went to the head office of the Phoenix Bridge Co. at Phoenixville, Pa. Mr. Cooper, when he heard of the observed deflection, sent a telegram which has given rise to numerous newspaper articles in the last few days. This was addressed to Phoenixville and not to Quebec, and read:

Add no more load to bridge till after due consideration of facts.

The same afternoon the bridge collapsed. This coincidence in time is not of course, proof of a caused connection between the deflection of chord A9L and the fall of the bridge, but the facts in themselves seem to establish a fairly substantial chain of plausibility. The thing to note is that a strut of any kind that is bent out of line is not in the best of shape to resist high compressive stresses. Increase of load, or small influences of purely fortuitous nature, may increase its deflection, and under certain conditions, as when the stress in the outer fibers reaches the elastic limit, a buckling failure by continued deflection is a necessary consequence. These circumstances offer some explanation of why this chord is found in the wreckage in badly buckled condition, whereas the other chord-sections exhibit no buckling.

What may have been the origin of the deflection noticed in this chord on Aug. 26 is not directly indicated; nor is there anything to tell why this deflection should have led to failure after remaining apparently unchanged for three days.

EARLIER MISHAPS OF A9L.—It appears that the history of this chord-section was not as uneventful as that of most of the other pieces of the steel work, and this history offers some support for the view that the section was slightly inferior to the others when it was set in place in the bridge. The chord A9L, it seems, had a short kink in one of the inner ribs before it left the shop, caused by some little awkwardness in handling the member. This kink, perhaps ½-in. deep and a foot or two long, was considered unsightly, but not harmful. We have heard it said that the chord later had bad luck during shipment, being involved in a railway wreck; whether this be true or not, the fact is really of little more than sentimental effect in the absence of knowledge as to how the member was involved and whether or not it was injured.

Somewhat more important is still another mishap, experienced in the storage yard a half mile south of the bridge site. While the chord section was being hoisted here, one of the hooks which held it broke, and the member fell flat on the ground on its top face. The field-splice plates at the end destined to adjoin chord A10L were bent or broken by striking a projection, and in turn they damaged the coverplate and the flange angles at the end. The damage was repaired, we understand, in workmanlike manner, the plates and angles being cut back and new end pieces spliced in. After these repairs the member was believed by all concerned to be quite up to standard, and in particular it was straight, we are told.

We confess our inability to conclude from the story of these mishaps, assuming their nature to have been as stated and the repairs conscientiously made, any great suggestion of alarm for this member as against a duplicate normal chord-section. It is only in connection with the subsequent events that the mishaps become prominent: the member in question actually deflected, it was completely destroyed by buckling when the bridge collapsed, and it is at the present moment perhaps the most suspicious point in the entire wreckage as regards causation of the fall.

In view of this, the prior history of the member offers to the mind some degree of basis for speculation on the question why this particular strut should have failed, while the others in similar service remained apparently sound, and why it should have failed at so low a stress.

The question of the re-erection of the bridge has not been fully decided, but on account of its immense economic advantage to the city and province of Quebec it is thought that the work will be carried on to a successful finish. Although the structure is primarily for railway purposes the necessity for a better entrance into Quebec led the Dominion, provincial and city governments each to contribute large sums of money toward the erection of the bridge. Throughout the work, then, the government has been largely interested in the successful prosecution of the project and one of the first official acts after the collapse was the appointment of Messrs. Henry Holgate and J. G. G. Kerry of Montreal, and Prof. J. Galbraith of Toronto, to investigate the accident and make an official report thereon. This commission is now at work. The bridge is the enterprise of the Quebec Bridge Co., of which Mr. E. A. Hoare, of Quebec, is Chief Engineer and Mr. Theodore Cooper, of New York City, Consulting Engineer. The substructure was built by Mr. M. P. Davis of Ottawa. The design and erection of the steel superstructure was let to the Phoenix Bridge Co., of Phoenixville, Pa. Mr. John Sterling Deans is Chief Engineer of the latter company and Mr. P. L. Szlapka the engineer to whom the design of the steel work is due.

FIG. 19. LOOKING EAST AT NORTH END OF BOTTOM-CHORD SECTION A 9 L.

At the right of the view the chord is bent in a semicircle and the four ribs are crushed together, returning downwardly toward the left of the picture, then bending back sharply in a semicircle and returning upwardly and to the right. A part of this last upwardly returning portion shows in the background and is marked "A 9 L West Center Rib," the direction of its south end being marked.

Fig. 20. A View Looking North and Somewhat Downward into the Second Bend of Bottom-Chord Section A 9 L.

The triangular patch of white at the extreme left is part of the exposed top face of one of the four ribs of this member. Turning up to the upper left-hand corner is the broken end of the west rib, the side at the right being its inner face; on its opposite face, remains of the flange-angle appear. The right-hand or easterly leg of the S-shaped form of this chord ascends upward to the right in the picture.

SEWAGE TREATMENT PLANTS UNDER CONSTRUCTION OR ORDERED IN PENNSYLVANIA.

A large number of sewage treatment plants are or are likely soon to be under construction in Pennsylvania, according to a recent statement by Mr. F. Herbert Snow, M. Am. Soc. C. E., Chief Engineer of the State Department of Health of Pennsylvania. This statement, which was made as recently as June 18, 1907 (see Proc. Eng. Soc. of Western Pa., for July), is as follows:

The city of Reading is building a modern sewage disposal plant, comprising septic tanks and sprinkling filters. This will be the first plant erected under the administration of the new Department of Health.

At Wayne, Delaware Co., a sewage purification plant comprising septic tanks, roughing filters and sand bed finishers is nearing completion. This work was decreed necessary by the Commissioner of Health.

The Commissioner ordered the discontinuance of the discharge of sewage into the natural water courses at West Chester. Plans for sewage and sewage works were submitted and approved. However, the electors overwhelmingly defeated the question of a bond issue for the purpose, so the matter may have to be settled in the courts.

Norristown has gone ahead in defiance of State law and constructed a new sewerage system with an outlet into the Schuylkill River. The power of the State to enforce the provisions of Act 182 of 1905 will be tested in this instance. The constitutionality of the law whereby the Commissioner of Health has power to prevent and remove nuisances and menaces has been upheld by the highest court in the commonwealth.

The city of York built 43 miles of separate sewers during the last three years, costing $400,000. That city has been denied the use of this investment until an intercepting sewer and sewage works shall have been built, estimated to cost $400,000. Plans thereof have been approved and the question of funds is to be decided at a special election.

The towns in the Schuylkill Valley are about to be ordered to discontinue the discharge of sewage into the streams. Many of the sewers, as at Pottstown, are private sewers and the remedy is a general public sewerage system. Months are required in the working out of the problem. A summary order to take the sewage out of the stream would be most impracticable, so it was decided in the Pottstown case.

Philadelphia has been given five years in which to prepare plans for intercepting the sewage now discharged at its many outfalls and for improved disposal of its sewage. That city has over 1,000 miles of sewers and discharges 300,000,000 gals. of sewage daily into the Schuylkill and Delaware. So the problem is an enormous one. Some of Philadelphia's sewers contribute to the pollution of its own water supply. In proceeding to improve the quality of the raw river water of the Schuylkill and Delaware above Philadelphia, the State has had to take cognizance of the conditions in that city also.

Pittsburg cannot reasonably expect the State to campaign against towns whose sewage goes into the streams above Pittsburg and overlook the fact that Pittsburg's sewage pollutes the water supply of towns on the Ohio River below. The law is operative for all. However, in the administration of the law it at once becomes apparent to the trained mind accustomed to grappling with large problems, that the successful working out of plans and methods of procedure relative to the sewers and the disposal problem for Pittsburg must extend over a period of years and require a relatively long time for consummation. This emphasizes the importance of an early comprehensive study.

The Delaware, Susquehanna, Ohio, Allegheny and Monongahela rivers are interstate streams.

The Governors of New Jersey and Pennsylvania met in 1906 to inaugurate a policy of cooperation and later the proper authorities of the three States of New York, New Jersey and Pennsylvania, met and agreed upon a common policy for the Allegheny, Susquehanna and Delaware rivers. Most of the pollution of the three streams occurs within the territory of Pennsylvania. New Jersey has already enforced the erection of a number of sewage disposal works in the Delaware basin. Trenton is to have five years in which to study her problem. Camden will not have to take up the question sooner than Philadelphia.

Bristol, Pa., is the first town above Philadelphia on the Delaware. Sewerage and disposal works were ordered by the Commissioner. Plans have been submitted and approved, and the money voted by the citizens. The works will be built this year.

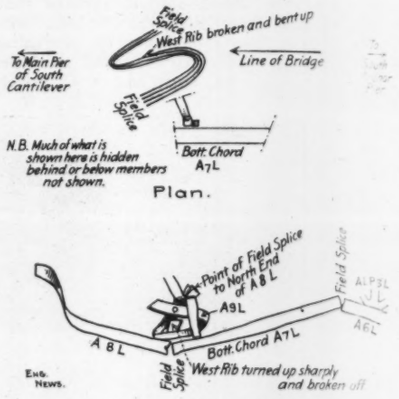

Fig. 21. Diagram Sketches of the Location and Condition of Bottom Chord A 9 L in the Wreckage.

This is the only chord section in the anchor arm that is buckled bodily. Many chord sections are broken, twisted, bent, and thrown far out of position relative to other parts of the wreckage, but only this one is buckled.

The city of Easton has been given three years in which to provide treatment works. South Bethlehem a similar time. Allentown is considering the problem.

The towns on the Upper Lehigh and Schuylkill are in the coal fields, so also are those along a part of the North Branch of the Susquehanna and some of the tributaries of the main stream. In the Lackawanna River, sometimes the flow is six parts mine drainage to one part upland water. Sewage organisms do not live long in this acid stream, or they are very rapidly precipitated.* Tests do not reveal the presence of coli in the river water a few feet down stream below the large sewer outlets of Scranton. In the coal fields of East and West Pennsylvania, the problem of sewage disposal is connected to some degree with the germicidal and disinfecting effect of mine drainage. The department is considering the question of the sewage disposal of perhaps 25 municipalities in the coal fields, with special references to mine drainage.

Several towns along the Lower Susquehanna and the upper branches have been permitted to discharge into the streams for three years.

Below Pittsburg, in the Ohio basin, the city of New Castle has, in conformity with an order of the Commis-

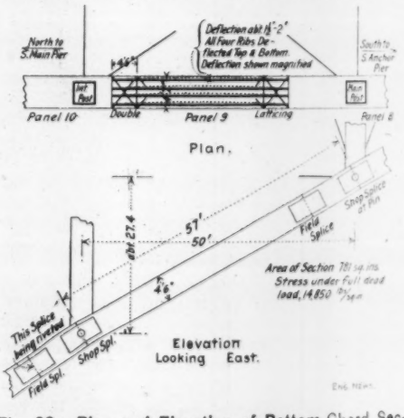

Fig. 22. Plan and Elevation of Bottom-Chord Section A 9 L, Second from Main Pier in West Anchor-Arm Truss.

The drawing is diagrammatic, but is correctly to scale. The lateral deflection of the ribs at their middle is, however, shown to about twice or three times its actual size as measured on Aug. 27.

*[But see "The Relation of Sedimentation and Acid Mine Wastes to the Potability of the Lower Monongahela River," by S. J. Lewis, Assistant Engineer U. S. Geological Survey; Engineering News, March 15, 1906.]

sioner submitted plans for sewage disposal works. Greenville, on the Shenango above New Castle, was denied the right to build sewers without disposal works. Plans thereof have since been prepared and approved and construction work is in progress. The plant comprises septic tanks, contact beds and sand filters.

Zelienople, Ellwood City, New Wilmington, West Middlesex, Emsworth, Edgeworth, Osborne and Carrick have been required to prepare plans for purification works.

Washington Borough, Washington Co., was ordered to abate a nuisance in Chartiers Creek caused by town sewage. The borough adopted and is now building sewage works in compliance with plans approved by the State Department. The works comprise septic tanks and sprinkling filters.

Glenshaw, East Brady, Ford City, Meadville, Oil City, Titusville, Edinboro, Cambridge Springs, Youngsville, Warren, Johnsonburg, Ligonier, St. Marys, Indiana, Blairsville, Saltsburg, Derry, Versailles, Stoystown and Meyersdale are some of the places above Pittsburg in the Allegheny and Monongahela basins which have been permitted to extend sewers, provided plans for sewage treatment works be designed within three years.

In a year from now, if all matters pending in the Department are decreed, there will have been ordered the preparation of plans for the treatment of municipal sewage at at least 100 places in the State.

AN UNUSUAL ACCIDENT occurred to the Manhattan Limited eastbound train on the Pennsylvania R. R., on Aug. 30, near Huntingdon, Pa. Running at 60 mi. per hr., the train shaved a box-car standing too close to the main track on a siding; the cab was lifted from the engine and thrown clear of the tracks (though neither the engineer nor the fireman was injured) and a gash ripped the entire length of one side of each of the seven Pullman cars of the train, without injuring a passenger.

AN EXCEPTIONALLY SERIOUS COLLISION OF electric cars occurred Aug. 30 near Charleston, Ill., on the Mattoon and Charleston interurban line. A car crowded with people going to the county fair was run into by a freight and express car. Both cars were running at high speed, and 14 people were killed, while nearly 50 were injured. It appears from the testimony given before the coroner's jury that the express car was one which had been operated without a fixed running schedule, the motorman thereof knowing the running time of other cars and apparently using his judgment as to the best means of dodging them. Both motormen have been arrested pending further investigation.

A CONCRETE DAM across the Boardman River, four miles south of Traverse City, Mich., failed on Aug. 23. It was built three years ago by the Boardman River Electric Light & Power Co., and supplied power and light to Traverse City. The power plant, according to report, is being operated from the old dam, but not at full capacity. Scouring of the foundations, or "backwash," is said to be the cause of the failure.

FOUR LARGE MANUFACTURING PLANTS were destroyed by fire in Jersey City, N. J., during the night of Aug. 30. The fire started in the four-story brick plant of Snare & Triest, Contracting Engineers, swept the yards of the Uvalde Asphalt Co., on the Morris & Essex Canal basin, and burned the plants of the A. L. Causse Mfg. Co., makers of candied fruits, and the Manhattan Electrical Supply Co. The estimated damage done in two hours was $350,000, of which the Snare & Triest plant represents $150,000 and that of the A. L. Causse Mfg. Co. $125,000. Explosion among some cans of lubricating oil in the basement of the Snare & Triest plant is thought to have been the cause.

AN EVIDENT ATTEMPT TO DYNAMITE A BRIDGE was made near Philadelphia on Sept. 2, where the Baltimore & Ohio R. R. crosses Darby Creek. The bridge is being built by the Youngstown Construction Co., of Youngstown, Ohio. The company has recently had labor troubles with its men, through its refusal to bind itself to employ only union men, and the attempt is believed to have been an outgrowth of these troubles. Fifteen sticks of dynamite had been placed beneath the structure, but only five were exploded. The falsework was completely wrecked.

THE AMBROSE CHANNEL, the new deep waterway from New York Harbor to Sandy Hook, was used by the big Cunard liner "Caronia" in leaving port on Aug. 27. The liner made the passage successfully, and saved a half-hour in the usual time between her pier and Sandy Hook; she was drawing 30 ft. forward and 30 ft. 3 ins. aft, and traveled through at a speed of 10 knots. It was to test the channel, before bringing the new turbine liner "Lusitania," through it, that the Cunard Co. obtained permission to try it first with the "Caronia." The "Lusitania" will leave Liverpool on Sept. 7, and will steam a race with the "Lucania," holder of the world's transatlantic record, from Queenstown to New York.

VETERAN ENGINEERS who served with the Army of the Potomac during the Civil War met on Aug. 29 at the Everett House, New York City, for their 37th annual reunion. The engineers were members of the Fifteenth and Fiftieth New York Engineers' Brigade, Army of the Potomac.

THE NEW MINING BUILDING of the University of California, at Berkeley, was dedicated on Aug. 23. It is the gift of Mrs. Phebe Hearst, and cost about $1,000,000.

AN INGENIOUS METER-CHEATING DEVICE was recently discovered in New York City. It consisted essentially of a powerful electro-magnet built to fit down over the top of an ordinary direct-current recording watt-meter so that its poles are near the fields of the meter. On being supplied with current from the lighting circuit it neutralizes the normal field magnetization of the watt-meter and imposes its own stronger reversed magnetic field upon the meter armature and causes reversed rotation. It is stated that a few hours use of the apparatus once a week reduces the true reading 60% and that the device has been operated largely in saloons.

ELECTRIC MOTIVE POWER FOR CHICAGO RAILway Terminals is under investigation as to its advisability, largely on the score of smoke prevention. Very recently an official party composed of Mayor F. A. Busse, Dr. W. A. Evans (Health Commissioner), Mr. W. H. Wilson (Controller), Mr. M. H. Foreman (Chairman, Aldermanic Committee on Transportation), Mr. J. M. Glen (Secretary, Illinois Manufacturers' Association), and Mr. J. E. Donnelly (Chairman, Chicago Smoke Commission), arrived in New York City. One day was spent in examining the system of the New York Central & Hudson River R. R., at the invitation of Vice-President W. J. Wilgus, and under his guidance. It has been stated that Mr. Wilgus will examine the Chicago situation after leaving the active service of the New York Central, on Oct. 1.

ELECTRIC TRACTION on the Chicago and Evanston branch of the Chicago, Milwaukee & St. Paul Ry. is to be introduced within a few months, the railway company having at last accepted the city's ordinance providing for this work. The change has been proposed for some years, but the provisions of the ordinance have not been satisfactory to the company. A connection will be made with the Wilson Ave. line of the Northwestern Elevated Ry., and all passenger trains will be run down-town to the elevated loop. The portion of the line between Wilson Ave. and the Union Station will not be equipped for electric traction, and will be used only for freight traffic.

A RAPID TRANSIT SUBWAY between Boston and Cambridge, Mass., has been under consideration for some months past and will be the subject of a hearing before the Massachusetts State Railway Commission on Sept. 11, 12 and 13. At the hearing there will be considered plans, filed as required by law, by the Boston Elevated Railway Co. The proposed subway would have two tracks and would probably begin at the Park St. station, near Boston Common, extend to the Boston end of the recently completed bridge to Cambridge, pass over the bridge to Cambridge, then continue beneath Main St. and Massachusetts Ave. to Harvard Square. The total length would be about 3½ miles. It is reported that the city of Cambridge and the railroad company are not wholly agreed as to all the details of construction, the number and location of stations, etc. Mr. Walter C. Wardwell is Mayor and Mr. L. M. Hastings is City Engineer of Cambridge. Gen. William A. Bancroft is President of the Boston Elevated Railway Co., with offices at 101 Milk St., Boston.

EIGHT-CAR TRAINS on the Boston Elevated lines are projected in plans and petitions filed with the Massachusetts Railroad Commission. It is expected that this addition to the service will avoid present congestion at stations. All platforms will be lengthened and additional structures will be necessary.

THE CHICAGO DRAINAGE CANAL was connected with the water-power extension at Lockport, Ill., on Aug. 30. This was effected by the opening of the butterfly dam at the entrance of the head-race, admitting water to the power canal and forebay. The cofferdam at the entrance had been blown up and removed a few days before. When the power plant is in operation the flow of the main canal will continue through the extension to the plant and thence through the turbines and the canal-boat lock, and over the two adjustable dams to a tail-race discharging into the Desplaines River. The present outfall and controlling works at Lockport will then be used only in emergency, when the power canal is shut off. The butterfly dam by which this power canal can be closed, is a steel structure resembling an enormous lock gate turning on vertical bearings at the middle. Normally it will stand parallel with the channel, with its ends protected by concrete piers.

PERSONALS.

Mr. E. B. Priest, Chief Engineer of the Lake Superior Southern Ry., with offices at Oshkosh, Wis., has resigned.

Mr. Arthur E. Loder, formerly First Assistant Engineer of the U. S. Office of Public Roads, has been appointed Chief Engineer to the Los Angeles County (Cal.) Highway Commission.

Mr. A. W. Thompson, Division Superintendent of the Baltimore & Ohio R. R., has been appointed Chief Engineer of Maintenance of Way, succeeding Mr. John B. Dickson, whose resignation we noted last week.

Mr. Charles T. Hutchison, Manager of the mining machinery department of the Union Iron Works, of San Francisco, resigned recently to take a like position with the Joshua Hendy Iron Works, of San Francisco.

Mr. L. A. Waterbury, Assoc. M. Am. Soc. C. E., for the past four years Instructor in Civil Engineering at the University of Illinois, has been appointed Professor of Civil Engineering at the University of Arizona, at Tucson.

Mr. E. W. Cunningham has resigned as Erecting Superintendent for the Pittsburg Filter Mfg. Co., to accept a position with Bowman Bros., Contractors, of McKeesport, in charge of the construction of the new filtration plant at that city.

Mr. Geo. W. Caye has been appointed Assistant to the Vice-President and General Manager, also Purchasing Agent, of the Grand Trunk Pacific Ry. The appointment became effective Sept. 1. His headquarters will be at Winnipeg, Manitoba.

Mr. W. A. Leland, M. Am. Soc. C. E., formerly Resident Engineer for the Southern Power Co., at Great Falls, S. C., has accepted the position of Chief Engineer and Resident Manager for the Rockingham Power Co., with headquarters at Rockingham, N. C.

Messrs. C. S. Burns, M. Am. Soc. C. E., and R. E. McDonnel, M. West. Soc. E., forming the firm of Burns & McDonnel, Civil, Hydraulic and Sanitary Engineers, of Kansas City, Mo., have removed their offices from the Dwight Building to the Scarritt Building.

Mr. John H. Griffith, Assoc. Mem. Am. Soc. C. E., formerly Engineer of Construction for the Metallurgical Company of America, 52 Broadway, New York City, has accepted the Assistant Professorship of Civil Engineering at the University of Michigan, at Ann Arbor.

Mr. J. W. Buzzell has resigned as General Manager for Frank B. Gilbreth, Contractor, of 34 West 28th St., New York City, and has accepted a corresponding position with the Consolidated Engineering & Construction Co., with offices in the Metropolitan Life Building, New York City.

Mr. Hiram J. Slifer, M. Am. Soc. C. E., steam railway expert with J. G. White & Co., has opened an office as consulting engineer in the Wall St. Exchange Building, New York. He will make a specialty of steam railway practice. He was engaged in railway engineering work from 1878 to 1898, and then till 1905 was Superintendent and General Superintendent first of the Chicago & Northwestern Ry. and then of the Chicago, Rock Island & Pacific Ry.

Mr. J. B. Barnes has resigned as Superintendent of the Locomotive and Car Department of the Wabash R. R. Mr. E. F. Needham, Master Mechanic of the Springfield and Decatur divisions, succeeds him, with headquarters at St. Louis. Mr. Barnes will retire permanently from railroad work, in which he has been engaged for 46 years; he will make his home at Fort Wayne, Ind. Mr. Needham has served with the Wabash since 1880, when he began as an apprentice in the Fort Wayne shops.

Obituary.

Nicholas Van Tassel, for 40 years Chief Engineer of the Union Ferry Co., Brooklyn, N. Y., died in Brooklyn on Sept. 1.

Bernard J. McGrann, formerly a prominent railroad contractor of Lancaster, Pa., died at Lancaster on Aug. 28 at the age of 70.

Edwin S. Slack, for many years Superintendent of the Somerville (N. J.) Water Co., died on Aug. 27 at his home in Raritan, N. J. He was stricken with paralysis at Somerville the night before. Mr. Slack was 55 years old.

Alonzo R. Williams, Superintendent of the Fire Underwriters of New York, died on Sept. 2 at the King Edward Hotel, Toronto. He was attending a convention of insurance men when he was taken ill with toxaemia. Mr. Williams was 38 years old.

Arthur Henry Birks, Assoc. M. Am. Soc. C. E., Resident Engineer for the Phoenix Bridge Co., in charge of construction of the Quebec bridge, lost his life in the collapse of that structure. He was a graduate of the Massachusetts Institute of Technology, and was 32 years of age.

B. A. Yenser, General Foreman for the Phoenix Bridge Co., residing at Slavington, Pa.; J. L. Worley, Foreman, residing at Mauch Chunk, Pa., and J. W. Aderholdt,

Assistant Foreman, all engaged in the construction of the Quebec bridge, were killed when it fell. They had all been long in the employ of the company.

Edward Russell Coffin, Vice-President of the Electric Securities Corporation, of New York City, a prominent financier, and the son of Charles Albert Coffin, who is President of the General Electric Co., died on Sept. 2 at the Omaha General Hospital from strangulated hernia, while en route from San Francisco to New York City. He was 34 years of age.

Rear-Admiral Wm. Augustus Windsor, U. S. N., (retired) died on Aug. 29 at his home, 850 West End Ave., New York City, at the age of 65. He was educated in public and private schools of Baltimore, and later studied engineering in the drafting room and shops of the Baltimore & Ohio R. R. In 1862 he was appointed a third assistant engineer in the navy; passing through intermediate engineering grades, he became a Chief Engineer, with the rank of Commander, in 1889. In 1901 he was made a Captain, and the following year was retired with the rank of Rear-Admiral. In 1898 and 1899 he was Chief Engineer and head of the Department of Steam Engineering at the New York Navy Yard. Mr. Windsor was a member of the Society of Naval Architects and Marine Engineers.

ENGINEERING SOCIETIES.

COMING MEETINGS.

ASSOCIATION OF EDISON ILLUMINATING COMPANIES.
Sept. 10-12. Annual convention at Hot Springs, Va. Secy., Ernest H. Davis, Williamsport, Pa.

MASTER CAR AND LOCOMOTIVE PAINTERS' ASSOCIATION.
Sept. 10-13. Thirty-eighth annual convention at St. Paul, Minn. Secy., A. P. Dane, Reading, Mass.

NATIONAL ASSOCIATION OF STATIONARY ENGINEERS.
Sept. 10-17. Annual convention at Niagara Falls. Secy., F. W. Raven, 315 Dearborn St., Chicago.

NEW ENGLAND WATER-WORKS ASSOCIATION.
Sept. 11-13. Twenty-sixth annual convention at Springfield, Mass. Secy., Willard Kent, 715 Tremont Temple, Boston.

CANADIAN ELECTRICAL ASSOCIATION.
Sept. 11-13. Seventeenth annual convention at Montreal. Secy., T. S. Young, Confederation Life Building Toronto.

LEAGUE OF AMERICAN MUNICIPALITIES.
Sept. 18-20. Eleventh annual convention at Norfolk, Va. Secy., John MacVicar, 18 Broadway, New York City.

AMERICAN PUBLIC HEALTH ASSOCIATION.
Sept. 30-Oct. 4. Thirty-fifth annual meeting at Atlantic City, N. J. Secy., Dr. Chas. O. Probst, Columbus, Ohio.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS.
Oct. 1-4. Annual meeting at Detroit. Secy., Geo. W. Tillson, 831 Ocean Ave., Brooklyn, N. Y.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS.
Oct. 8. Annual meeting at Washington, D. C. Secy., Edw. A. Moseley, Interstate Commerce Commission, Washington, D. C.

RAILWAY SIGNAL ASSOCIATION.
Oct. 8-10. Twelfth annual meeting at Milwaukee. Secy., C. C. Rosenberg, Lehigh Valley R. R., South Bethlehem, Pa.

AMERICAN BOILER MANUFACTURERS' ASSOCIATION.
Oct. 8-10. Nineteenth annual convention at Atlanta, Ga. Secy., J. D. Farasey, Forest St. and Erie Ry., Cleveland, O.

AMERICAN ELECTROCHEMICAL SOCIETY.
Oct. 10-12. Annual fall meeting at New York City. Secy., Prof. J. W. Richards, Bethlehem, Pa.

AMERICAN STREET AND INTERURBAN RAILWAY ASSOCIATION.
Oct. 14-18. Annual convention of this and affiliated association at Atlantic City, N. J. Secy., Bernard V. Swenson, 29 West 39th St., New York City.

AMERICAN STREET AND INTERURBAN RAILWAY ENGINEERING ASSOCIATION.
Oct. 14-16. Annual convention at Atlantic City, N. J. (See preceding item.) Secy., S. W. Mower, Southwestern Traction Co., London, Ont.

ASSOCIATION OF RAILWAY SUPERINTENDENTS OF BRIDGES AND BUILDINGS.
Oct. 15-17. Annual meeting at Milwaukee. Secy., S. F. Patterson, Concord, N. H.

AMERICAN GAS INSTITUTE.
Oct. 16-18. Second annual meeting at Washington, D. C. Secy., Jas. W. Dunbar, New Albany, Ind.

RAILWAY SIGNAL ASSOCIATION.—A stated meeting will be held at the Great Northern Hotel, Chicago, on Sept. 10, with sessions at 10 a. m. and 2.30 p. m. The subject for consideration will be "Standard Specifications for Interlocking." At this meeting the report of the committee on that subject will be gone over in a general way, to give the committee opportunity for getting the views of other members preliminary to presentation of its report at the annual meeting at Milwaukee, when it will again be taken up and disposed of.

CENTRAL RAILWAY CLUB.—The next regular meeting and fall outing of the club will be held at Buffalo on Friday, Sept. 13. Members will assemble at the Iroquois at 10 a. m., then take a barge trip around the harbor and to the Lackawanna steel plant; a special train will convey the party about the plant. At a session on board the barge, Mr. John P. Kelly, of the Westinghouse Air-Brake Co., will present a paper on "Some of the Requirements of Modern Air-Brakes." Mr. H. D. Vought, 62 Liberty St., New York City, is Secretary.

INSTITUTE OF ARCHITECTS OF CANADA.—At the organization meeting in Montreal, Aug. 19-23, the provisional Board of Officers which we listed on Aug. 8 was unanimously elected for permanent service during the ensuing year. Seventy-seven architects responded to the call and enrolled as charter members of the Institute. Mr. F. W. Fitzpatrick, of Washington, D. C., presented a paper on "Uniformity in Building Laws," the recommendations in which were endorsed by resolutions. Ottawa, Ont., will be the headquarters city of the Institute, and the first regular meeting of the incorporated body will be held there.

IRON AND STEEL INSTITUTE.—The fall meeting will be held in Vienna, in the house of the Austrian Engineers' and Architects' Society, on Monday and Tuesday, Sept. 23 and 24. Papers scheduled for presentation are: "The Development of the Iron Industry of Austria since 1882," by W. Kestranek, Vienna; "The Styrian Erzberg Iron Ore Mines," by Prof. H. Bauerman; "Steel and Meteoric Iron," by Prof. F. Berwerth, Vienna; "Determination of the Quantity of Blast Furnace Gas for a Given Make of Pig Iron," by Prof. Josef von Ehrenwerth, Leoben; "Application of the Laws of Physical Chemistry to the Metallurgy of Iron," by Baron H. von Jüptner, Vienna; "Case Hardening of Mild Steel," by C. O. Bannister, London, and J. W. Lambert, Assoc. Inst. C. E., Woolwich; "A New Blue-Black Paint as a Preservative Covering for Iron," by F. J. R. Carulla, Derby; "Hardening of Steel," by L. Demozay, Unieux, France; "The Structure of Hardened Steel," by Percy Longmuir, Sheffield; "Case Hardening," by G. Shaw Scott, Birmingham; "Ageing of Mild Steel; Further Notes," by C. E. Stromeyer, M. Inst. C. E., Manchester; "Economical Distribution of Power from Blast Furnaces," by B. H. Thwaite, London.

AMERICAN GAS INSTITUTE.—At the second annual convention in Washington, Oct. 16-18, the following papers and reports are scheduled for presentation: "Depreciation," A. C. Humphreys; communication from New England Association by their Committee on Uniform Accounting and Depreciation; "Experience in Omaha on Delivering Uniform Candle Power to Consumers," Geo. H. Waring; "Obligations Imposed by the Possession of a Franchise," Chas. J. Dickey; "Instructions for Operating Recuperative Benches," W. A. Baehr; "Experiments in Carbonization," W. T. Fulweiler; "Electrolysis," Prof. Albert F. Ganz (Stevens Institute.) Reports of these committees: Methods of Taking Candle Power, Wm. H. Gartley, Chairman; Public Policy, E. G. Cowdery, Chairman; Making of Rates and Additional System of Costs, W. H. Gardiner, Chairman; Economic Balance between Calorific Value and Candle Power, Thos. D. Miller, Chairman; Board of Revision, W. H. Shattuck, Chairman; Electrolysis, A. G. Glasgow, Chairman; Pipe Standards, Walton Forstall, Chairman; Uniformity of Meters, Chas. H. Dickey, Chairman. The address of welcome will be delivered by Hon. H. B. F. MacFarland, President of the Board of Commissioners of the District of Columbia.

CANADIAN ELECTRICAL ASSOCIATION.—At the coming convention in Montreal, meetings will be held in the assembly hall of the Canadian Society of Civil Engineers, at 413 Dorchester St. West. An electrical exhibition will be held in the Government drill hall on Craig St.

Sessions begin on Wednesday, Sept. 11, at 10.30 a. m. After the President's address and committee reports the following papers have been scheduled for that day: "Electrical Heating and Cooking Devices," by A. B. Lambe; "Trials of the Operating Man," by M. A. Sammett; "Three-Wire Generators," by B. T. McCormick. The evening will be devoted to visiting the electrical exhibition.

Papers for the second day are: "High-Tension Insulators from an Engineering and Commercial Standpoint," by Clarence E. Delafield; "The Value of the Nernst Lamp to the Central Station," by A. E. Fleming; "Incandescent Lamps," by J. M. Robertson; "Frazil and Anchor Ice: The Difficulties They Cause at Hydraulic Plants; Some Remedies," by John Murphy, and "The Load Factor," by R. M. Wilson.

On the closing day two papers will be presented: "Modern Lighting Transformers," by G. P. Cole, and "The Responsibility of Electric Companies for Accidents," by Geo. H. Montgomery. Throughout the session elaborate plans for entertainment will be carried out.

ASSOCIATION OF RAILWAY SUPERINTENDENTS OF BRIDGES AND BUILDINGS.—At the Milwaukee convention to be held on Oct. 15, 16 and 17, the technical side of the sessions will take the form of reports of committees, special and standing, and not of individual papers.

A list of the subjects to which special investigating committees have been assigned follows; the name of the chairman of each is given: (I.) Experience in Concrete Bridges, Arches and Subways, W. H. Finley, C. & N. W. Ry.; (II.) Concrete Building Construction, A. O. Cunningham, Wabash R. R.; (III.) Experience as to Expansion and Contraction of Concrete Walls, Either Reinforced or Plain, A. S. Markley, C. & E. I. R. R.; (IV.) Action of Sea Water on Concrete, (a) Made in and Sunk in Water, (b) Deposited Direct in Water, G. Aldrich, N. Y., N. H. & H. R. R.; (V.) Recent Experience in the Use of Wooden and Asbestos Smoke Jacks for Engine Houses, J. H. Cummin, L. I. R. R.; (VI.) Combination Fastening and Lock for Rolling and Doors on Freight Houses and Other Buildings, A. Lichty, C. & N. W. Ry.; (VII.) Construction of and Guides for Lights on Draw-Bridges, J. N. L. E. & W. Ry.; (VIII.) Recent Experience protecting Steel Railroad Bridges against the Action Brine from Refrigerator Cars, R. P. Mills, N. Y. & H. R. R. R.

Standing subjects on which committees will report are as follows, with the chairman of the committee on each: (1) Pile and Frame-Trestle Bridges, W. E. Smith, M. & St. P. Ry.; (2) Water Supply, C. E. Thomas, C. R. R.; (3) Fire Protection, Wm. C. Carmichael, C. I. & P. Ry.; (4) Fences, Road Crossings and Cattle Guards, W. M. Noon, D. S. S. & A. Ry.; (5) Preservative for Wood and Metal, J. F. Parker, S. Cal. Ry.

OHIO ELECTRIC LIGHT ASSOCIATION.—The thirteenth annual convention was held at Toledo, Aug. 20-22. After the President's address at the opening session the following papers and reports were presented:

Aug. 20, "Factory Lighting," A. P. Biggs, Detroit Ed. Illum. Co., and J. Kermode, Cleveland Illum. Co.; Report of Committee on Uniform Accounting, F. E. Crawford, Library Bureau, Cleveland, and D. W. Low, Alliance Gas & Elec. Co.; "Luminous Arcs from the Standpoint of the Central Station Operator," H. P. Gratchill, Ashland Gas & Elec. Co.; Report of Committee on Electric Heating Devices, M. E. Turner, Cleveland Illum. Co.

Aug. 21, "Coöperative Commercialism in the Electrical Field," J. Robert Crouse, Cleveland; "The Best Form of Power for Stations of 500-KW. Capacity or Less," Prof. F. C. Caldwell, Ohio State University; Report of Committee on High Efficiency Lighting Units, C. C. Collins, Columbus Ry. & Light Co., and A. N. Cope, Columbus Public Service Co.; "Helps to a Solicitor," Frank Maunsell, Toledo Ry. & Light Co., J. D. Kenyon, Sheldon School of Chicago, and A. S. Miller, Dayton Lighting Co.; Report of Committee on Cost Determinations, M. E. Turner, and F. M. Tait, of Dayton.

Aug. 22, "Best Ways to Meet Gas and Gasoline Competition," F. H. Golding, Dayton Lighting Co.; Samuel Rust, Greenville Elec. Light & Power Co.; W. E. Russell, Massilon Light, Heat & Power Co.; Arthur Pomeroy, Cleveland Illum. Co.; E. T. Selig, Mt. Vernon Elec. Light Co., and W. C. Anderson, Canton Light, Heat & Power Co.

Officers elected for the ensuing year are: President, F. M. Tait, Dayton Lighting Co.; Vice-President, T. D. Buckwell, Toledo Ry. & Light Co.; Secretary-Treasurer, D. L. Gaskill, Greenville Elec. Light & Power Co. The total attendance was 302 delegates.

NEW ENGLAND WATER-WORKS ASSOCIATION.—At the twenty-sixth annual convention, Sept. 11 to 13, headquarters will be at the Cooley Hotel, Springfield. A. E. Martin, Superintendent of the Springfield Water Department, is Chairman of the Local Committee on Arrangements.

The association will assemble at noon on Wednesday, Sept. 11, and, following a welcome by Hon. Wm. E. Sanderson, Mayor of Springfield, the following paper will be read: "The Springfield Water-Works," by E. E. Lochridge, Chief Engineer—discussion by Allen Hazen, M. Am. Soc. C. E., and others. For the evening session these papers are scheduled: "Illustrated Talk on Australian Water-Works," by Allen Hazen; "Description of Plant at Peabody, Mass., involving Construction of Tunnel, New Reservoir, New Pumping Station and High-Duty Worthington Pump," by F. A. Barbour, M. Am. Soc. C. E., Boston; "Fire Hydrants," by Robert E. Newcomb, Holyoke.

Thursday's list of papers is: "Computation of the Value of Water Power, and the Damages Caused by the Diversion of Water Used for Power," by Chas. T. Main, Boston; "Damage Suits Against the City of Woonsocket, R. I., for Diversion of Water Power," by Frank E. Mills, City Engineer; "Diversion of Water Power," by Chas. E. Chandler, Norwich; "Water Rights," by Richard A. Hall, Essex Water Power Co., Lawrence, Mass.; "Waltham (Mass.) Reinforced Concrete Reservoir," by Bertram Brewer, City Engineer; "Waterproofing of Reservoirs," by Frank L. Fuller, M. Am. Soc. C. E., Boston; "Charles River Basin," by H. A. Miller, Chief Engineer Charles River Basin Commission, Boston; Report of Committee on Uniform Statistics, Joseph E. Beals, Middleboro, Mass., Chairman; Report of Committee on Standard Specifications for Cast-Iron Pipe, Dexter Brackett, M. Am. Soc. C. E., Boston, Chairman; "Cast-Iron Pipe Specifications," by Wm. R. Conard, Inspector, Burlington, N. J.

Friday will be devoted to excursions. The works of the Chapman Valve Co., at Indian Orchard, will be visited in the morning, and lunch taken there; in the afternoon the Springfield filtration plant will be inspected.